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DIGITIZED SONAR DATA LOG. PART I,(U)
APR 70 T D PLEMONS N00024-69-C-1129
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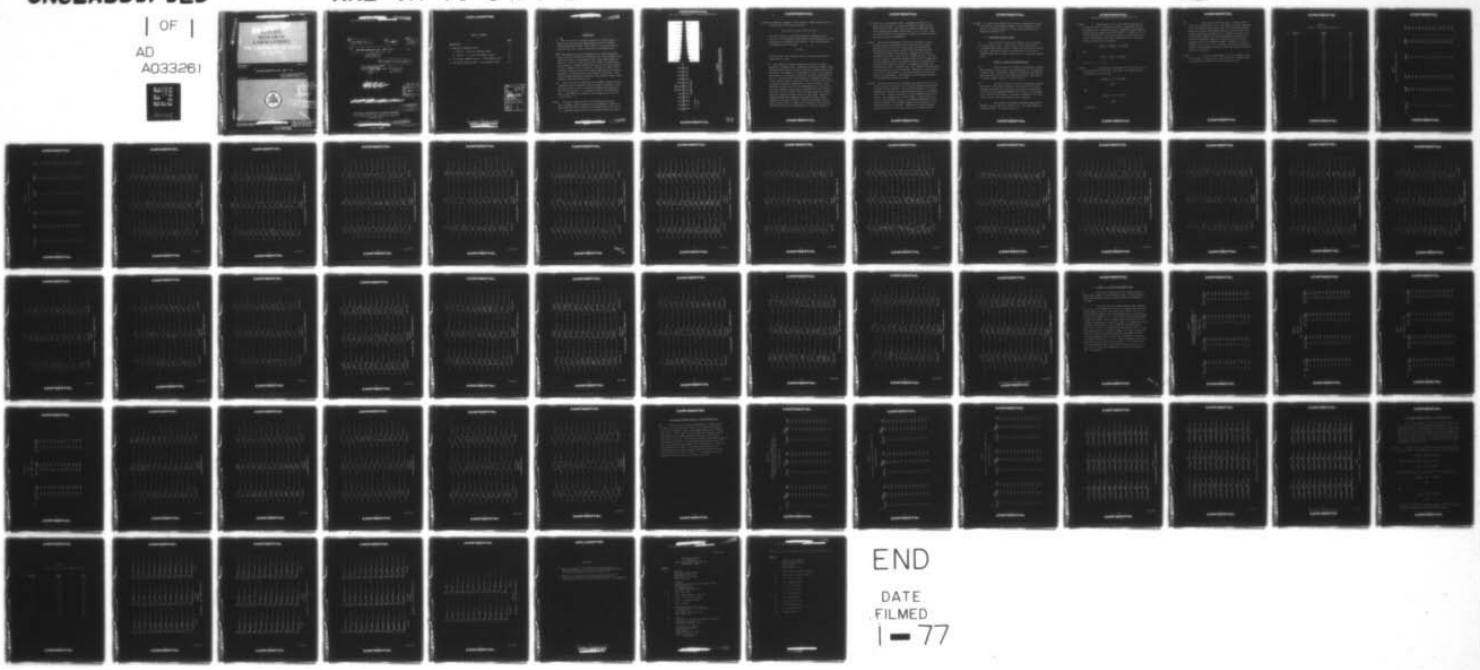

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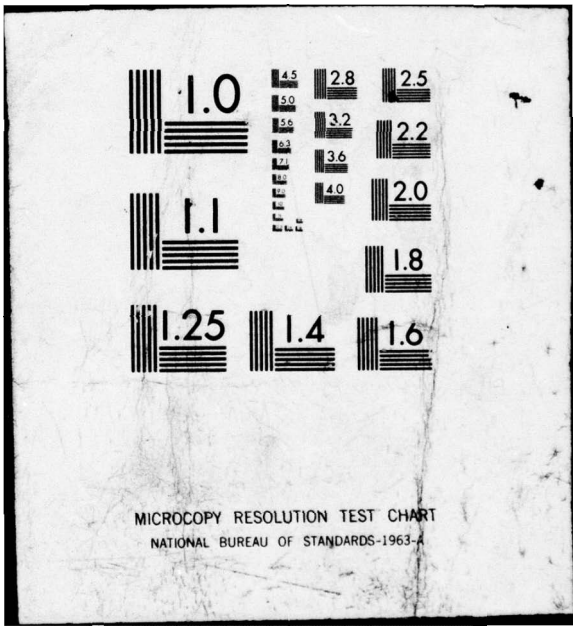
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APPLIED RESEARCH LABORATORIES

THE UNIVERSITY OF TEXAS AT AUSTIN

ARL-TM-70-5

9 April 1970

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DIGITIZED SONAR DATA LOG: PART I (U)

T.D. Plemons

NAVAL SHIP SYSTEMS COMMAND
Contract N00024-69-C-1129
Proj. Ser. No. SF 11121100, Task 8515

(14) ARL-TM-70-5-Pt-1

(11) 9 Apr 70

(12) 60 p.

(6) DIGITIZED SONAR DATA LOG. PART I, (U)

(10) T.D. Plemons

(15) N00024-69-C-1129

NAVAL SHIP SYSTEMS COMMAND
Contract N00024-69-C-1129
Proj. Ser. No. SF 11121100, Task 8515

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(17)

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INTRODUCTION

(C) This is the first of several collections of various types of digital data obtained by the Signal Physics Division of Applied Research Laboratories (ARL). Future data will not be restricted to echoes but will also contain collections of reverberation data.

(C) The digitized echoes were generated by the ASPECT (Acoustical Short Pulse Echo Classification Technique) mode of the AN/SQS-23 sonar. Echoes from targets corresponding to three target aspect angles are presented. This set of data should prove valuable to those persons doing research in signal processing since use of the digital computer now has a prominent role in this field. The data are readily available since they are stored on ARL's digital tapes which can be easily duplicated. Detailed records of these signals are included. These records provide information pertaining to the transmit signals, target geometry, digitizing technique, etc.

(C) Since the echoes were generated by the ASPECT transmission mode, a high data rate of information from the target is available in that the pulses within a burst of transmitted waveforms are separated by only 375 msec. Figure 1 is a schematic drawing of the ASPECT mode. Here is shown a set of 12 submarine echoes generated by a burst of 12 short pulses.

(U-FOUO) Two types of sampling were used in digitizing these data. Direct sampling refers to sampling the echo waveform, assumed to be narrow band with center frequency f_o and bandwidth W, at the rate of $4f_o$. Quadrature sampling refers to a sampling technique with which

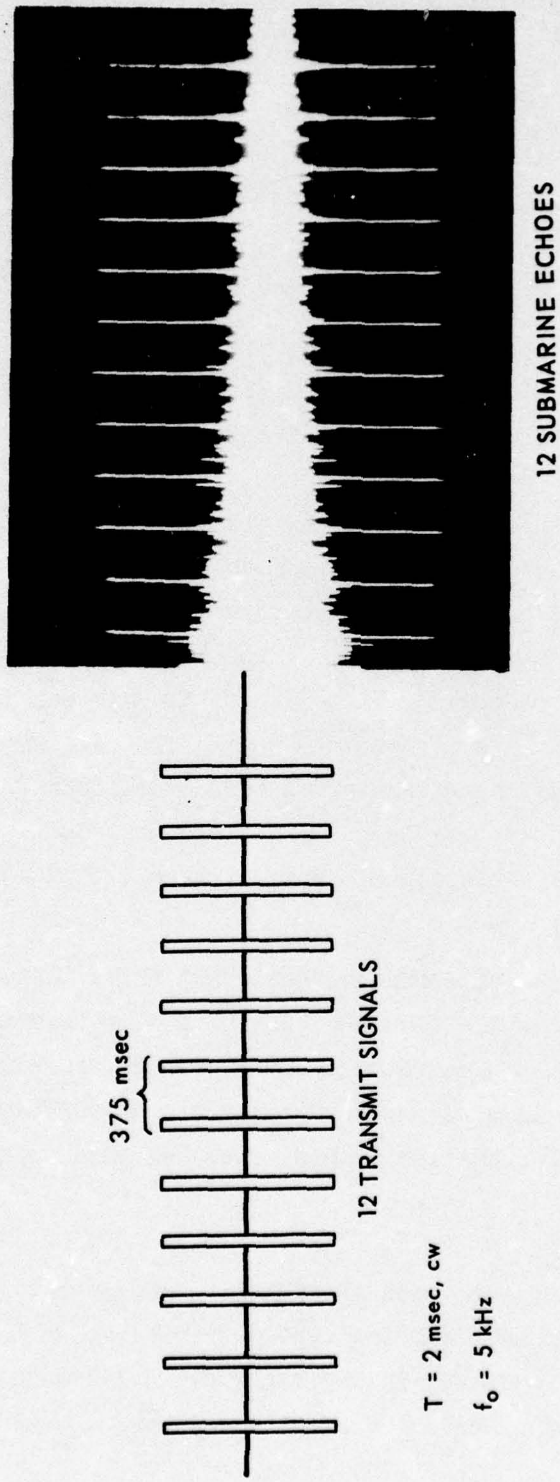

FIGURE 1
A BURST OF 12 TRANSMIT SIGNALS AND THE CORRESPONDING SET OF SUBMARINE ECHOES

ARL - UT
AS - 69 - 607
TDP - JEW
6 - 26 - 69

(U-FOUO) the quadrature components of the signal are obtained directly (Ref. 1). If the echo y(t) is written in the form

$$y(t) = X(t) \cos 2\pi f_o t + Y(t) \sin 2\pi f_o t \quad ,$$

then X(t) and Y(t) are called the quadrature components of the echo y(t). All information, other than the carrier frequency f_o, concerning y(t) is contained in X(t) and Y(t). Since these functions are bandlimited to the interval

$$|f| \leq \frac{W}{2} \quad ,$$

they are of much lower frequency than y(t) and hence the required sampling rate is lower.

(C) These data were obtained originally in analog form by ARL personnel in September 1965. Conversion from analog to digital format occurred during the past two years as specific research needs for the data arose. One example of the usefulness of such a data collection can be seen in an ARL report on echo-echo correlation characteristics (Ref. 2). The beam aspect echoes display a considerable variation in the envelope structure from echo to echo. It would be of interest to know the statistical characteristics of this variation. Some important questions that should be investigated are: Is the variation purely random or does it have a deterministic nature? What is the source of this variation? Why do the beam aspect data display a much lower consistency than do the bow or stern data? Would non-submarine targets with submarine-like geometry exhibit similar variations in envelope structure? Accurate determination of the epoch of these echoes is another area of research. This problem is discussed briefly in this memorandum, but no attempt was made to

(C) attack it in any persistent effort. Highlight structure of the echoes merits attention. Of particular interest is again the beam aspect data since here can be seen the decrease in range resolution as the transmit pulse length increases from 1 to 2 to 5 msec. These are only a very few of the questions or problems concerned with these data that are open to investigation.

(U-FOUO) Each echo is represented by a plot of its envelope. A small interval precedes the beginning of the echo epoch and a similar interval follows the end of the epoch. Epoch was determined by measuring the time occurrence of the 50% level of some consistent or repeatable feature of the envelope. Repeatable refers here to consistency from echo to echo, and not to within one echo. The set was then "aligned" using these threshold points to form a common time or phase among the echoes. An ensemble average of the aligned envelopes was then computed and plotted. The average of several noise envelopes will tend to a constant level, with respect to time (provided the noise process is locally stationary). Whenever the echo is present in the set, a time variation in the average envelope occurs and the epoch can be approximated. The accuracy of this technique increases as the signal-to-noise ratio increases.

(U-FOUO) The envelope was chosen to determine the epoch since it is a more slowly varying time function than is the high frequency waveform which we refer to as the amplitude. The uncertainty inherent in a finite sampling rate would cause the computed average amplitude to mistakenly tend to zero. Accurate calculation of epoch is hampered by any noise present. Also averaging over a finite number of echoes produces an error in the computation of epoch. An optimum determination of epoch was not attempted. The averaging technique was used because of its simplicity and ease of execution. However, the interval preceding and following each echo does allow for error in calculated epoch.

(U-FOUO) The data are presented in three sections corresponding to beam, stern, and bow aspect submarine targets. At the beginning of each section is a brief description of the data and associated plots, digitizing techniques, etc.

A. Beam Aspect Submarine Echoes

(C) The collection of beam aspect submarine echoes is divided into two groups, A and B. Group A refers to data collected on 15 November 1965, while the data in Group B was collected on 16 November 1965. The echoes of Group A were generated by 1 and 2 msec transmit pulses and the echoes of Group B by 1, 2, and 5 msec transmit pulses.

1. Group A: 1 and 2 msec Transmit Pulses

(C) Group A consists of two parts corresponding to transmit pulse lengths of 1 and 2 msec. The transmit pulse is a cw waveform of frequency 5 kHz. The data were sampled in quadrature, each component being sampled with a rate of 2500 samples per second. Each burst of 12 transmit signals results in a set of 12 echoes.

(C) The digitized data are stored on ARL computer tape 649. Each record on this tape corresponds to an entire set of 12 echoes. Therefore, associated with each record are 12 pairs of numbers each of which give the beginning (IFROM) and end (ITO) of the 12 envelope plots. The odd record numbers in each pair correspond to the X components and the even record numbers to the Y components.

(C) The destroyer and submarine maintained approximately parallel courses, each with a speed of 4 kt. The target aspect was 84 deg from stern. The range was 4000 yd.

(U-FOUO) Corresponding to the 2 msec transmit pulse there are 18 echo sets, each set containing 12 echoes. Each plotted echo is 120 samples long. Therefore, each plot corresponds to approximately 48 msec since the sample rate was 2500 $(\text{sec})^{-1}$. In Tables I, II, and III the IFROM and ITO of the plot of the first echo in each set is listed. The IFROMs and ITOs of the remaining 11 echoes in each set can be calculated from the formulas

$$(\text{IFROM})_n = (\text{IFROM})_1 + (n-1)(936) \quad ,$$

and

$$(\text{ITO})_n = (\text{ITO})_1 + (n-1)(936) \quad ,$$

for n = 1, 2, ..., 11, 12.

(U-FOUO) As an example, the IFROM and ITO of the first plot of the third set are 580 and 700, respectively. The IFROM and ITO of the fifth plot of this set are

$$(\text{IFROM})_5 = 580 + (5-1)(936)$$

$$= 4324$$

and

$$(\text{ITO})_5 = 700 + (5-1)(936)$$

$$= 4444 \quad ,$$

respectively.

(C) Following these tables are Figs. 2 through 7 which contain the individual echo plots. Each column of 12 plots represents a set of 12 echoes resulting from a burst of 12 transmitted signals. Below each column are three numbers written in the form $\ell(m,n)$. The integer ℓ denotes the particular set of 12 echoes, and m and n are record numbers (computer tape 649) corresponding, respectively, to the X and Y quadrature components. There are 18 echo sets corresponding to the 2 msec transmitted signal. Therefore ℓ, in Figs. 2 through 7, varies from 1 to 18. Similarly the echo sets resulting from the 1 msec transmitted signals are described by Tables II and III and Figs. 8 through 24.

(U-FOUO) The plots corresponding to the 1 msec transmit pulses are 90 samples (= 36 msec) long. The calculation of IFROMs and ITOs for these plots is identical to that of the 2 msec data.

TABLE I

Group A: 2 msec Transmit Pulse (U)

(C)	Set No.	IFROM	ITO
	1	614	734
	2	617	737
	3	580	760
	4	517	637
	5	515	635
	6	518	638
	7	520	640
	8	526	648
	9	527	647
	10	531	651
	11	529	649
	12	531	651
	13	534	654
	14	536	656
	15	535	655
	16	543	663
	17	551	671
	18	560	680

TABLE II

Group A: 1 msec Transmit Pulse (U)

(C)

Set No.	IFROM	ITO	Set No.	IFROM	ITO
1	579	669	14	519	609
2	582	679	15	499	589
3	592	682	16	510	600
4	601	691	17	506	596
5	608	698	18	512	602
6	614	704	19	524	614
7	618	708	20	519	609
8	622	712	21	530	620
9	622	712	22	461	551
10	630	720	23	459	549
11	629	719	24	468	558
12	653	743	25	480	570
13	572	662	26	478	568

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TABLE III

Group A: 1 msec Transmit Pulse (U)

(C)

Set No.	IFROM	ITO	Set No.	IFROM	ITO
27	481	571	40	501	591
28	489	579	41	493	591
29	492	582	42	498	588
30	501	591	43	501	591
31	501	591	44	504	594
32	514	604	45	506	596
33	469	559	46	511	601
34	458	548	47	512	602
35	469	559	48	511	601
36	490	580	49	513	603
37	486	576	50	516	606
38	493	583	51	518	608
39	497	587	52	520	610

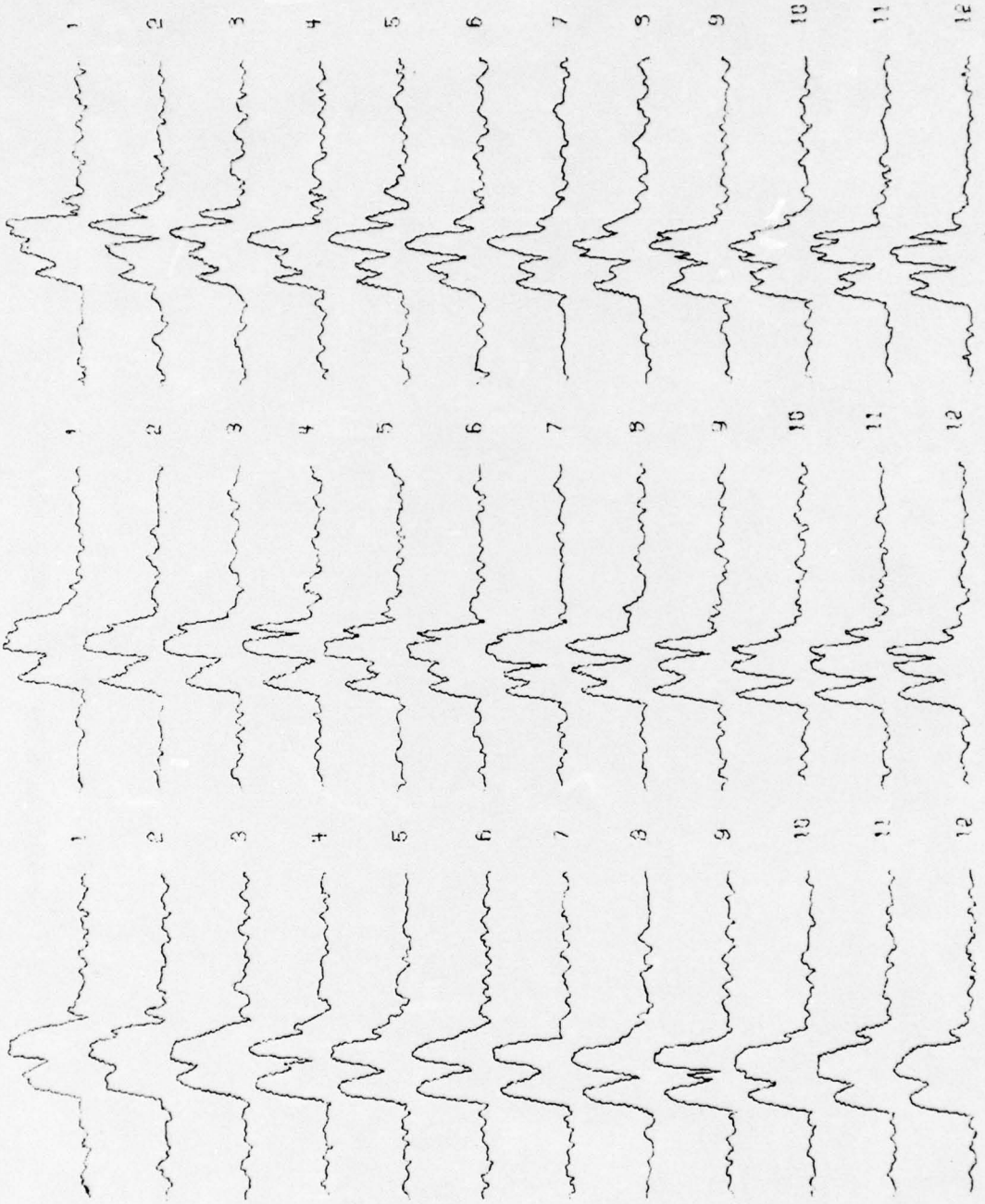


FIGURE 2

84 deg BEAM ASPECT: 2 msec TRANSMIT PULSE (U)

AS-70-220

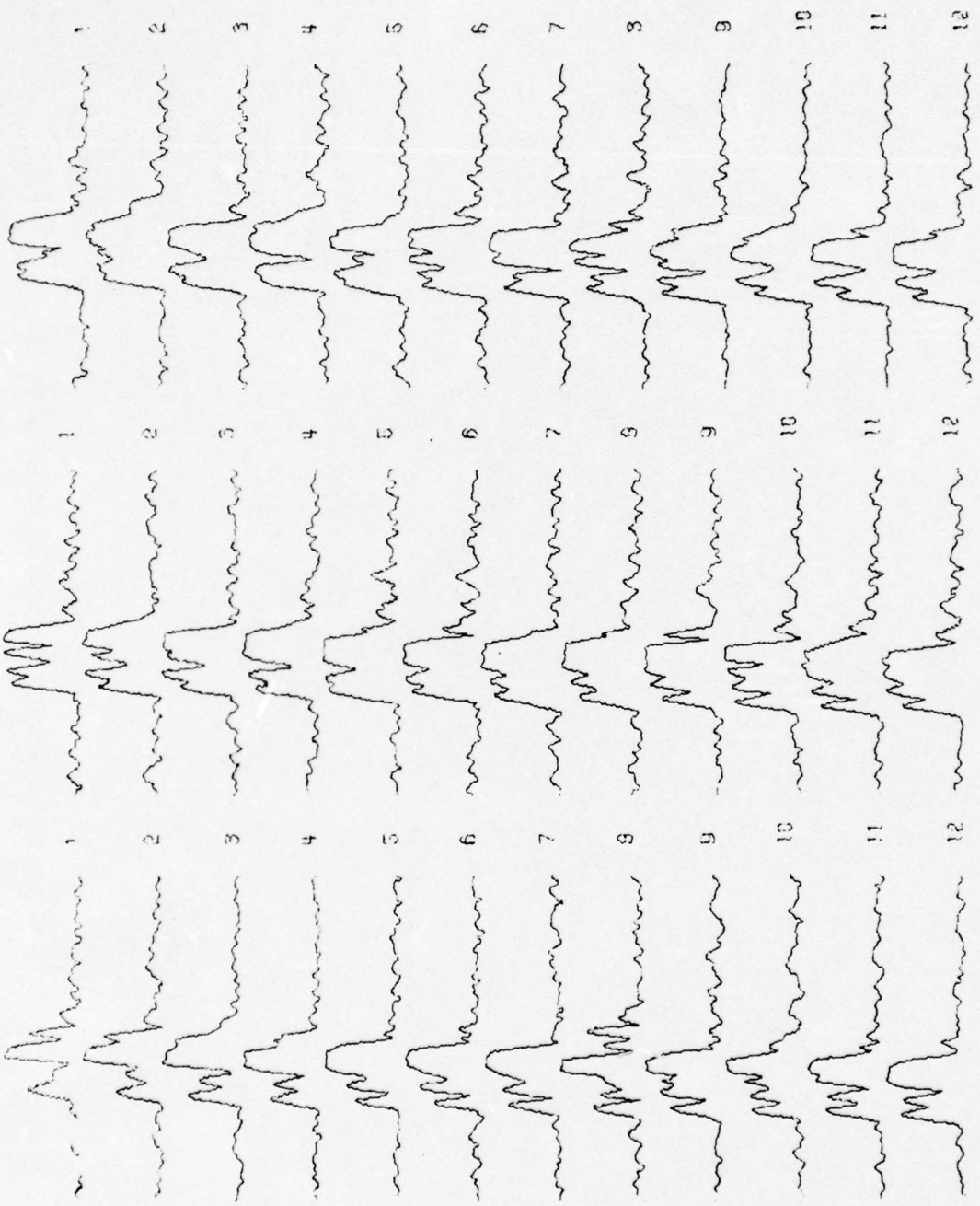
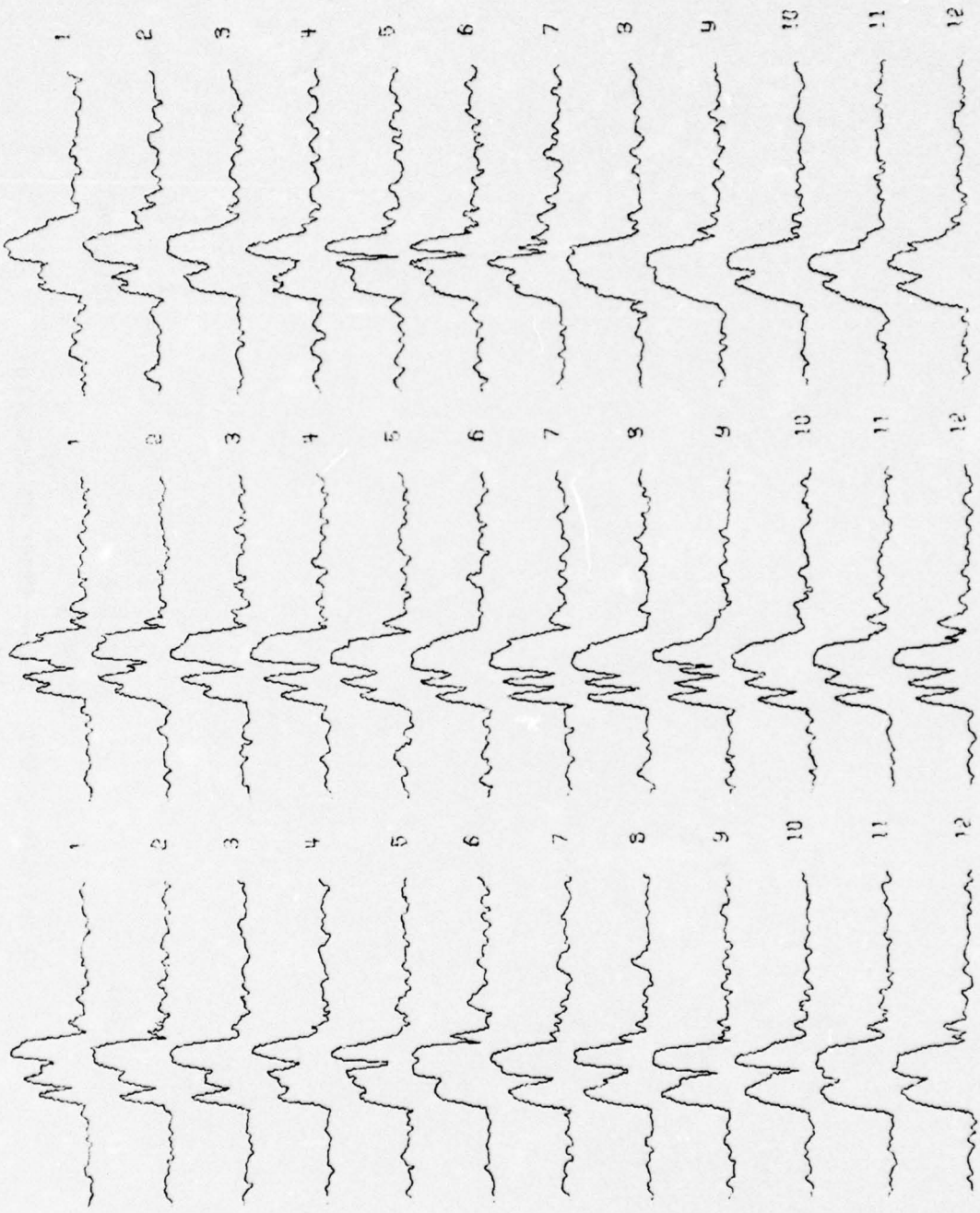


FIGURE 3

84 deg BEAM ASPECT: 2 msec TRANSMIT PULSE (U)

AS-70-221



7(13,14) 8(15,16) 9(17,18)

FIGURE 4

84 deg BEAM ASPECT: 2 msec TRANSMIT PULSE (U)

AS-70-222

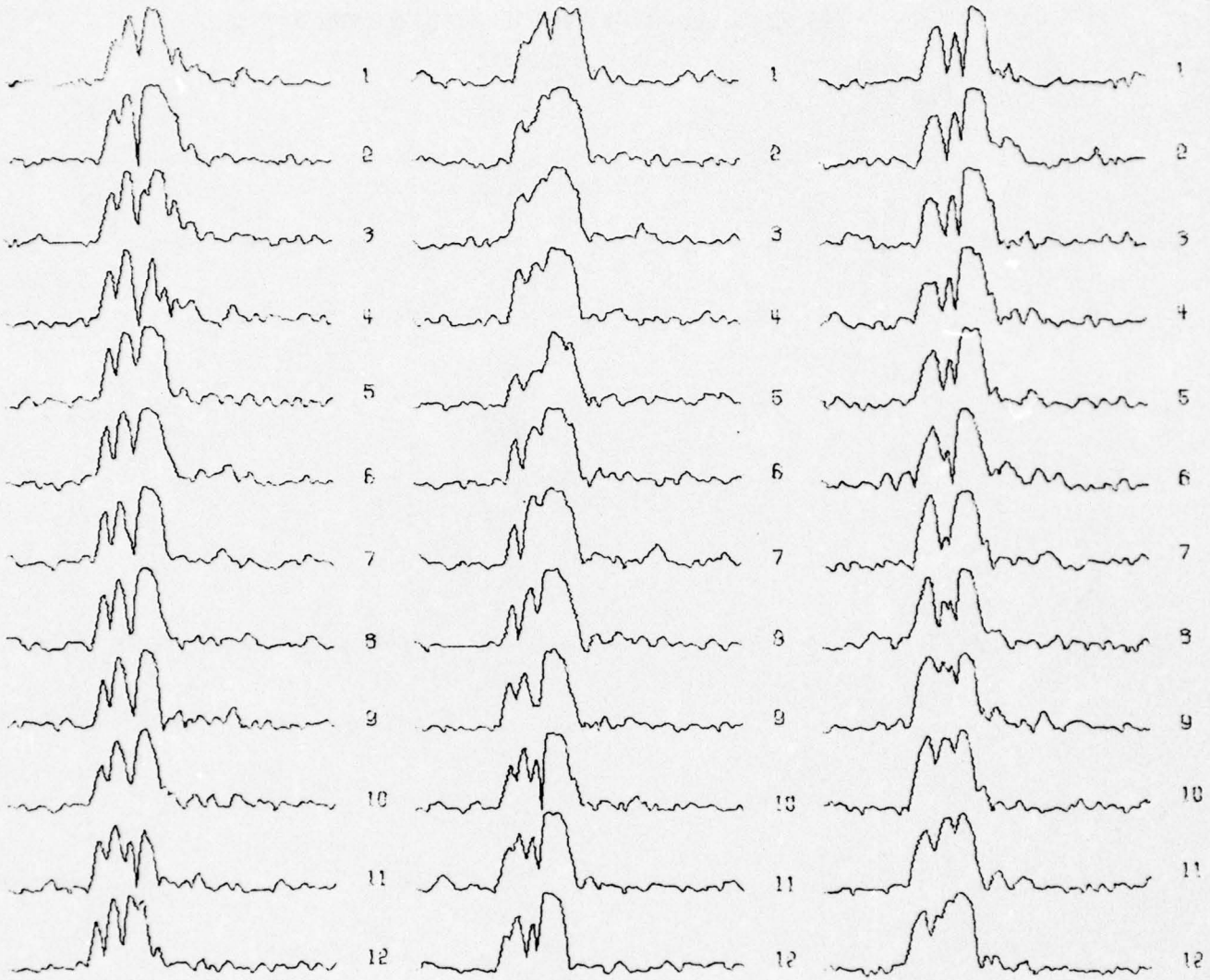


FIGURE 5

84 deg BEAM ASPECT: 2 msec TRANSMIT PULSE (U)

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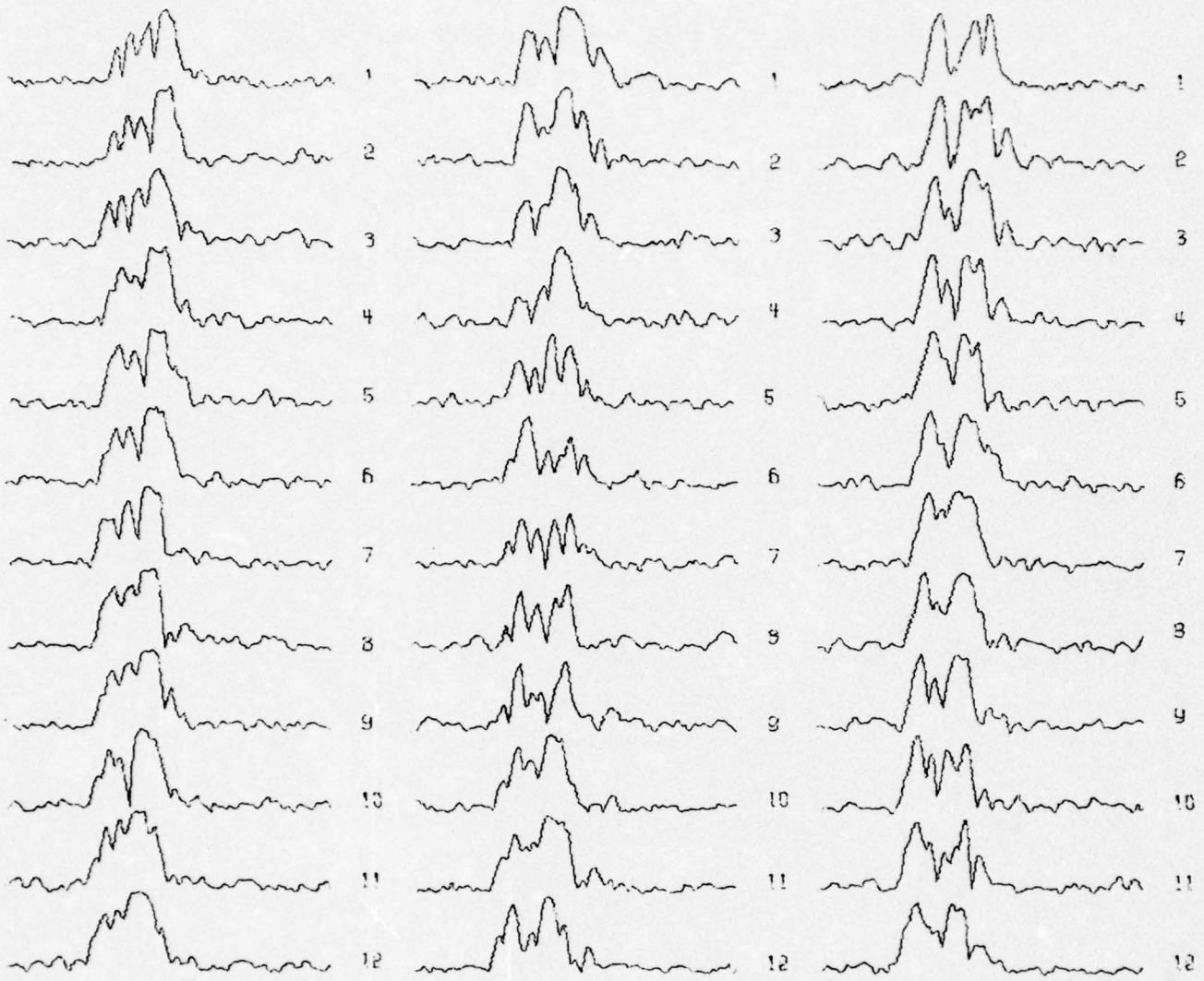


FIGURE 6

84 deg BEAM ASPECT: 2 msec TRANSMIT PULSE (U)

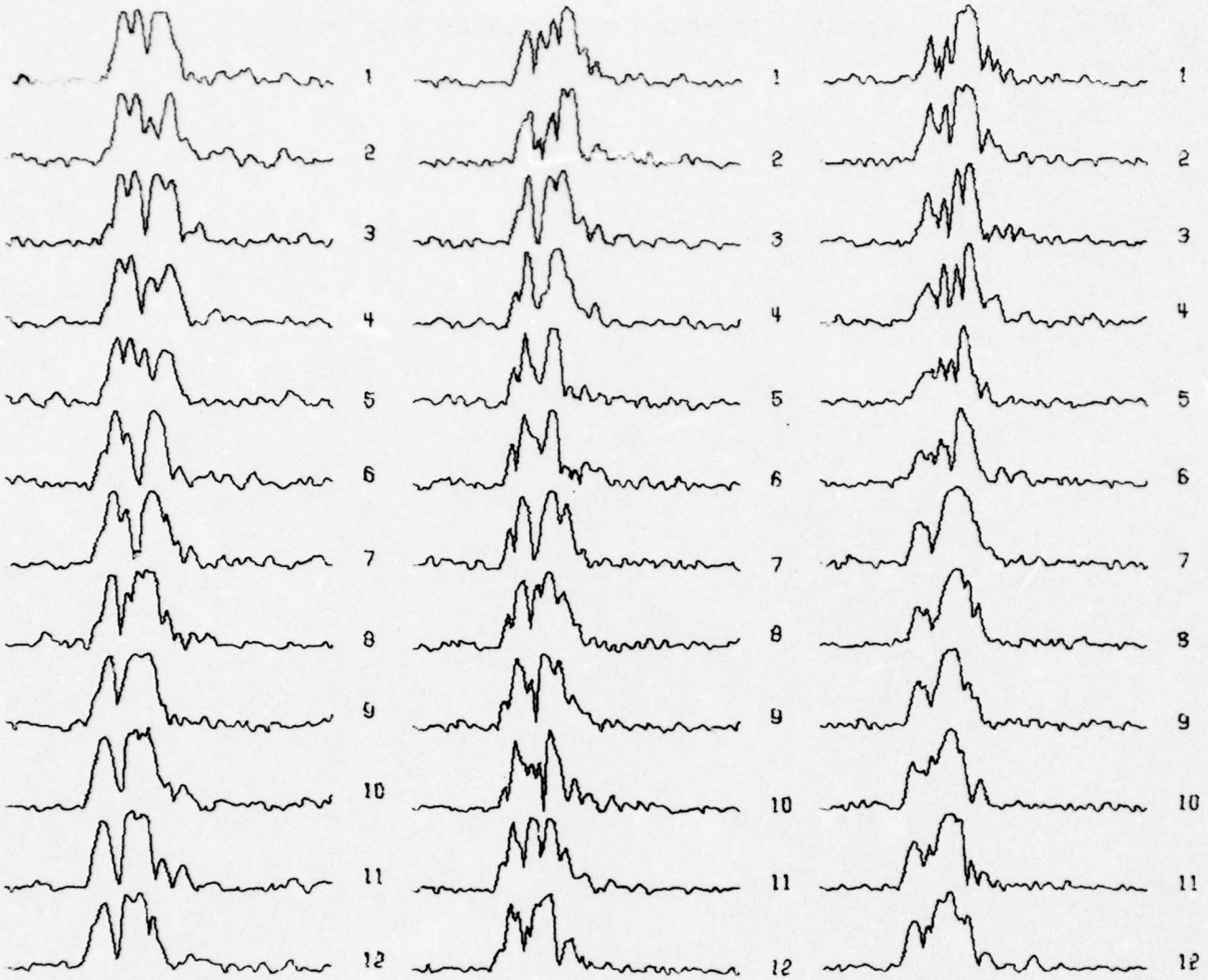
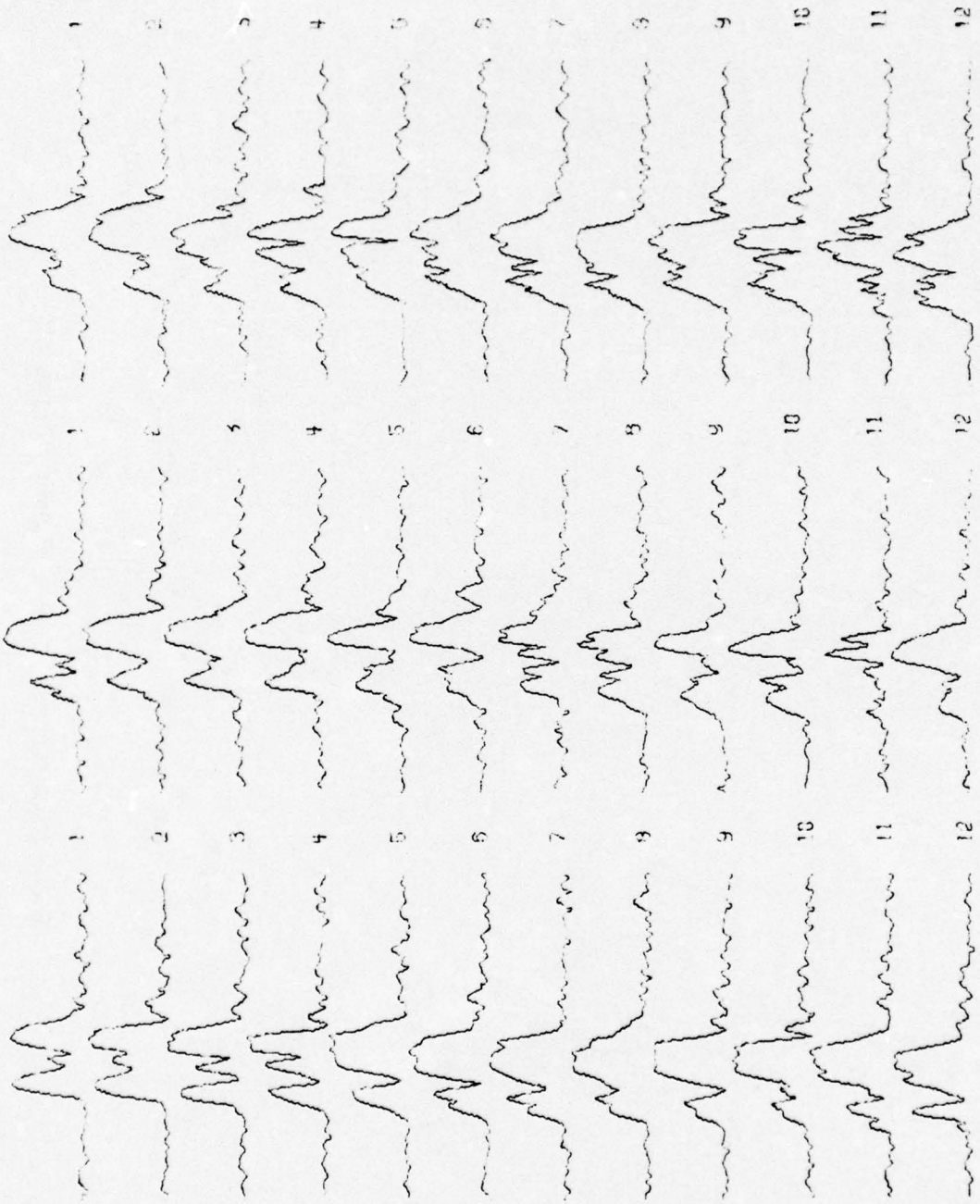


FIGURE 7

84 deg BEAM ASPECT: 2 msec TRANSMIT PULSE (U)



1(37,38) 2(39,40) 3(41,42)

FIGURE 8

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-226

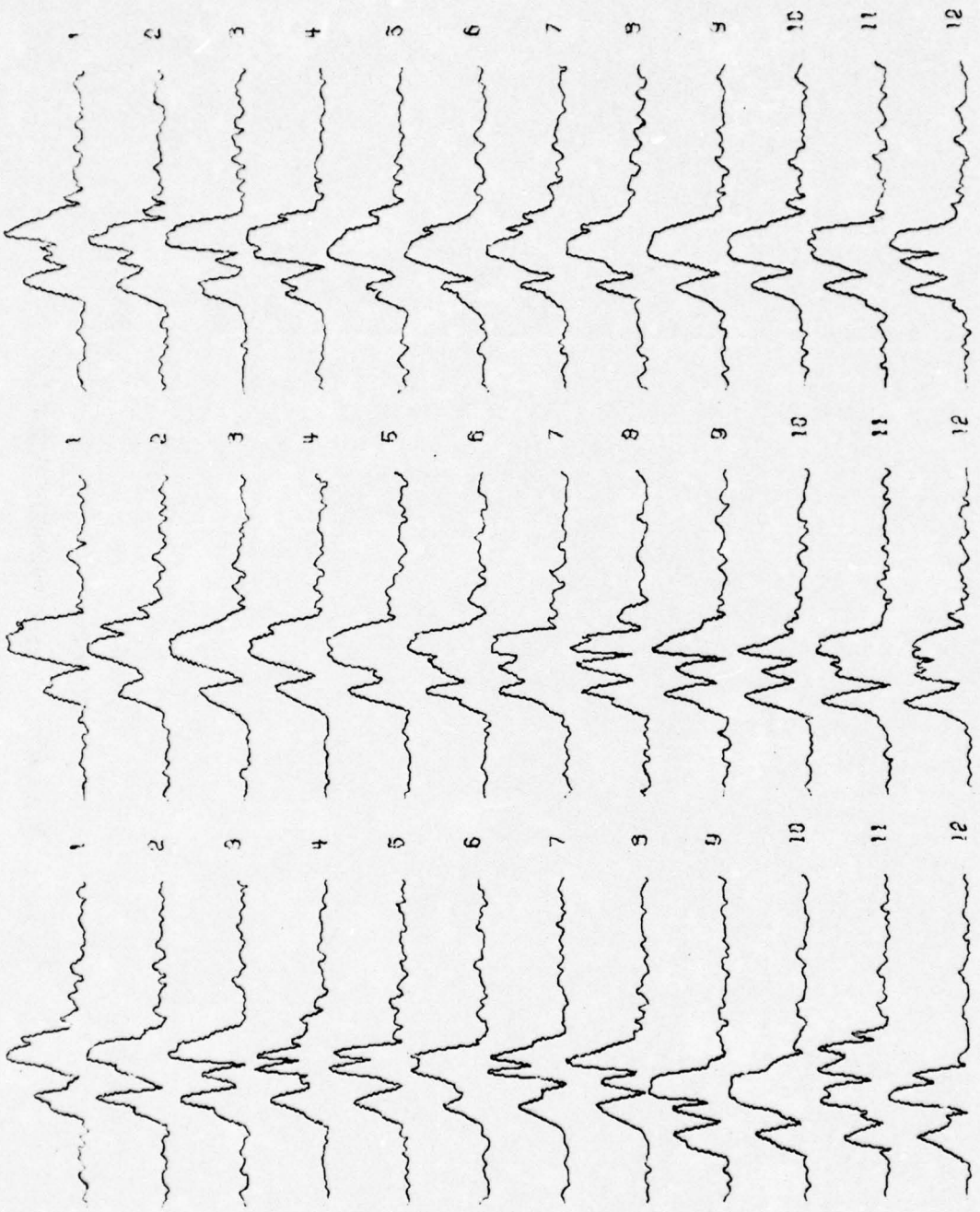


FIGURE 9

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-227

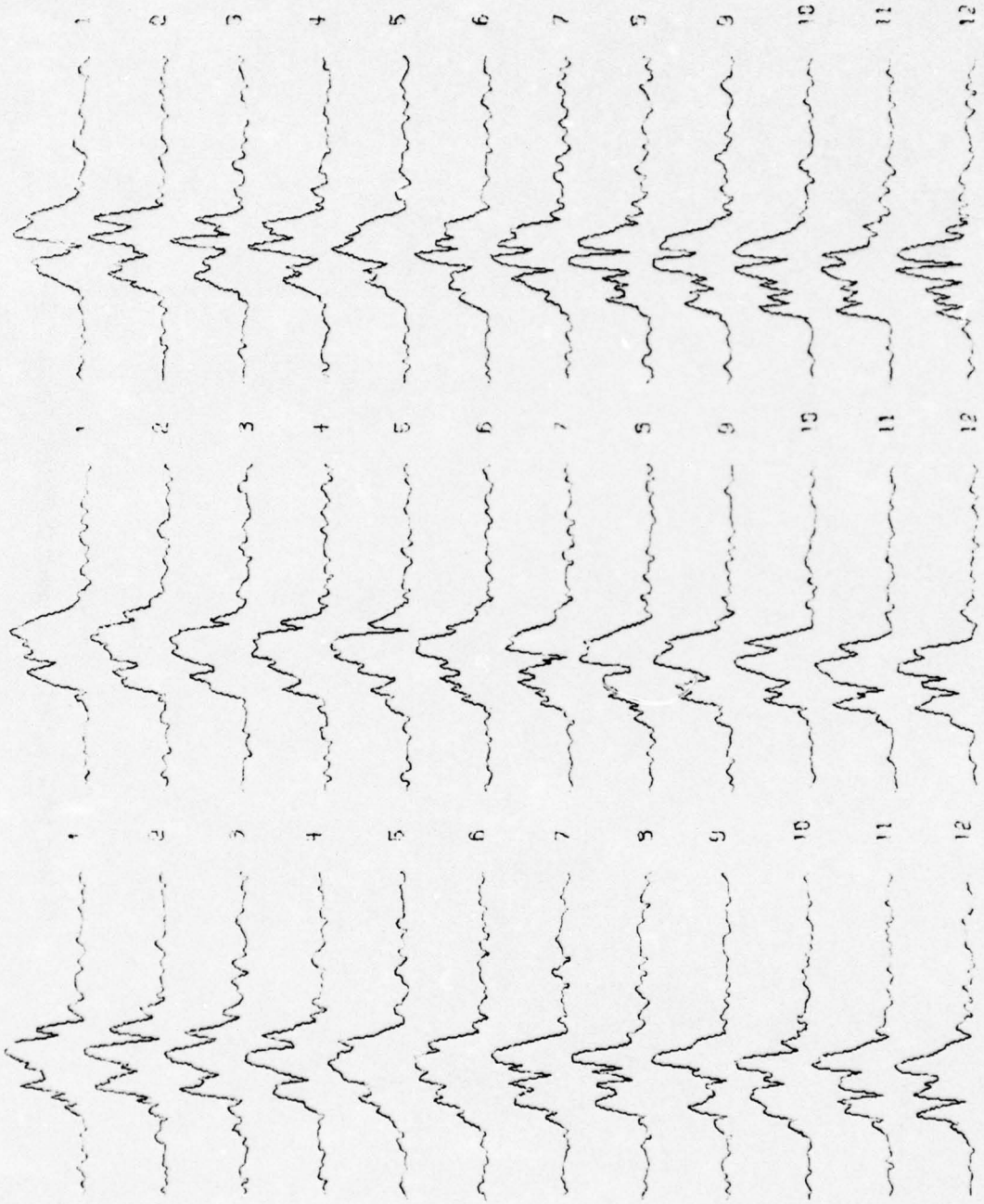
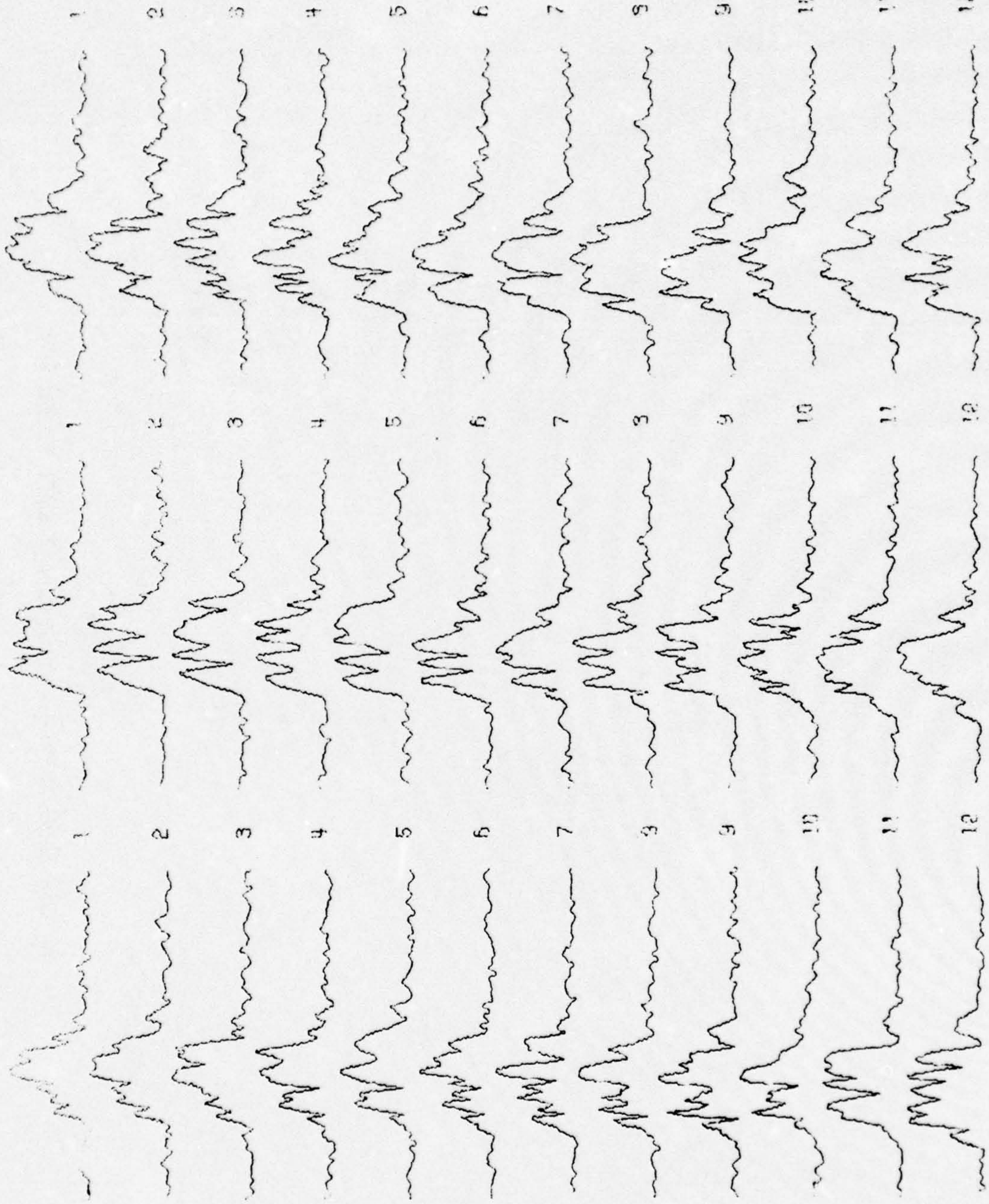


FIGURE 10

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-228

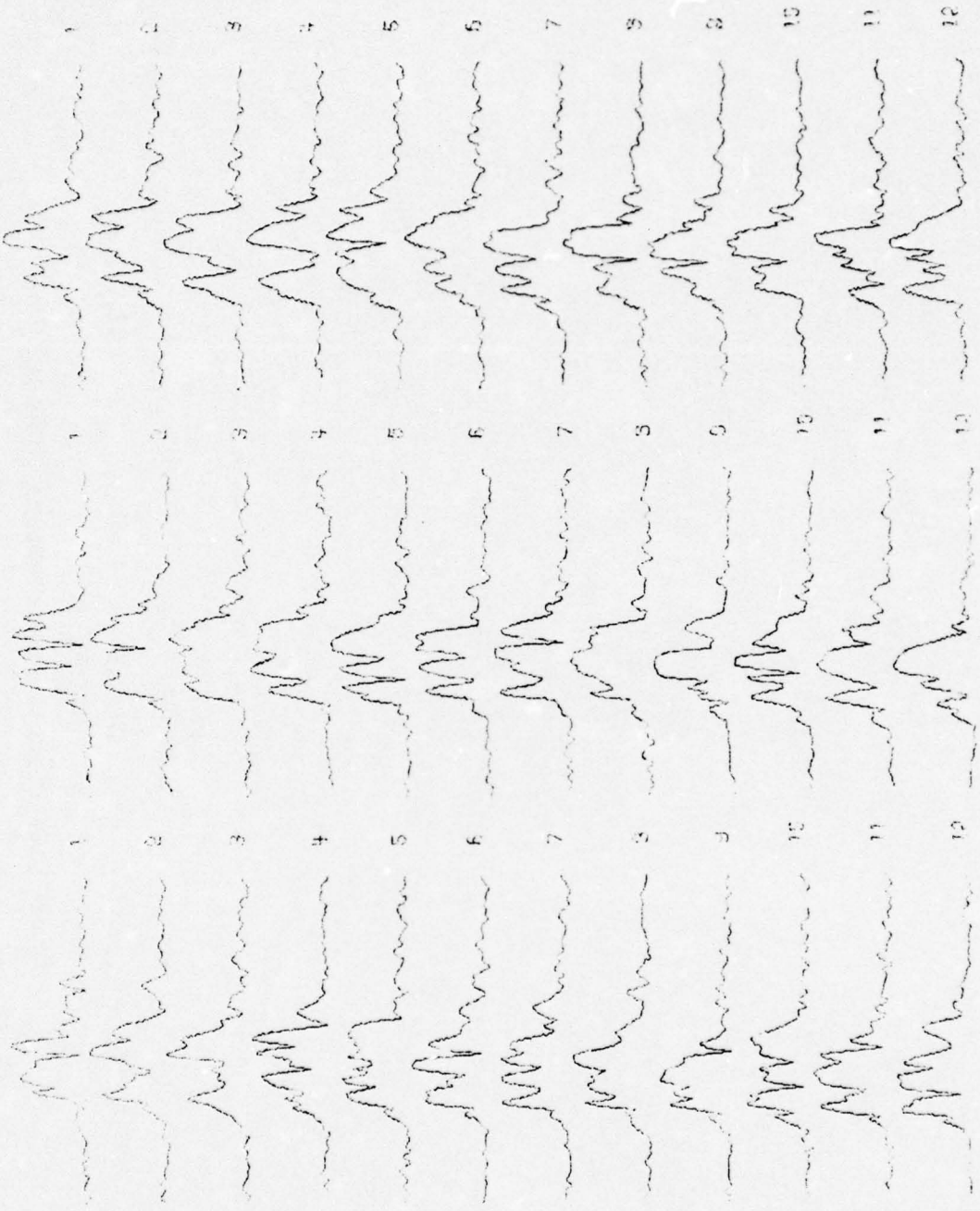


10(55,56) 11(57,58) 12(59,60)

FIGURE 11

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

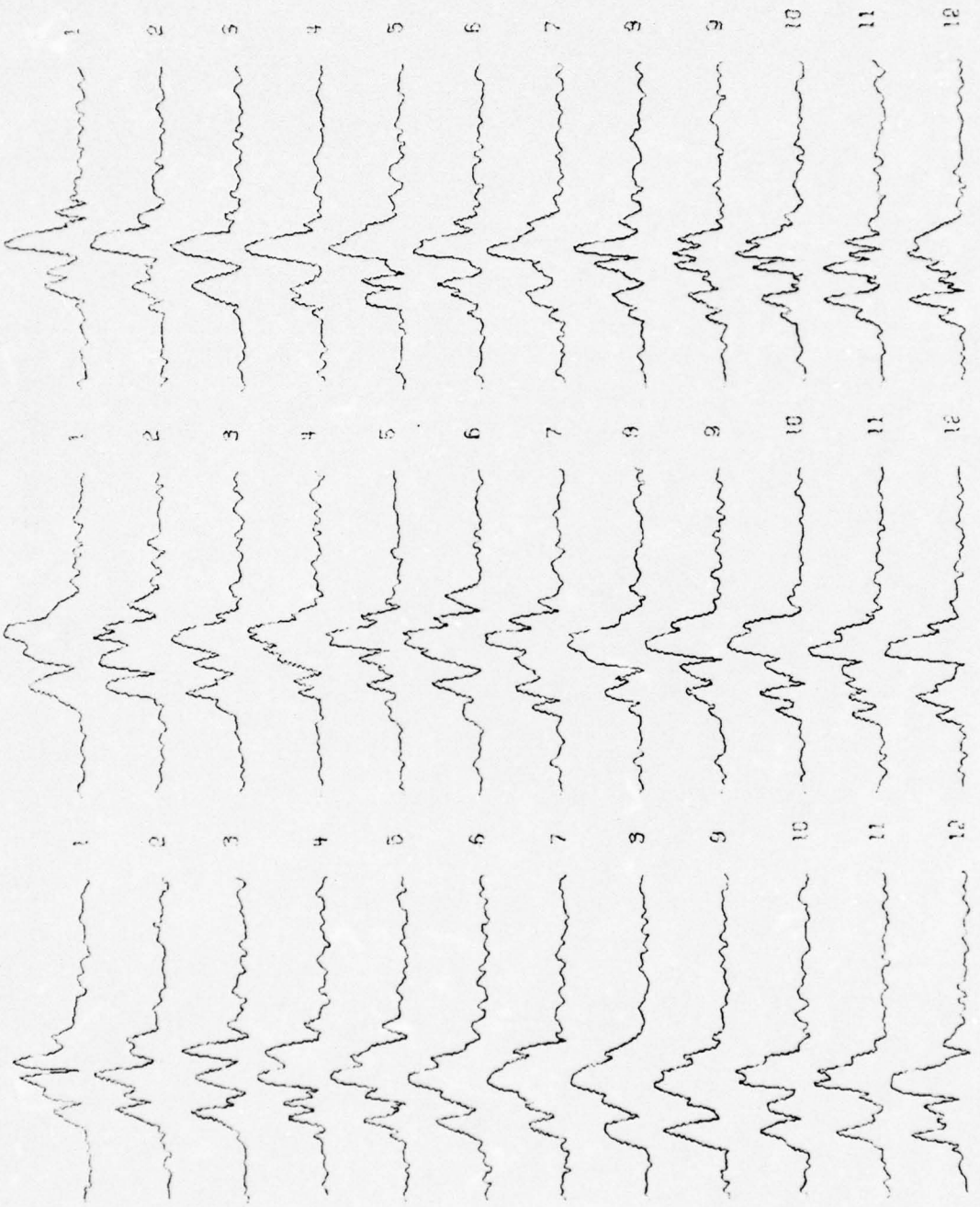
AS-70-229



84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

FIGURE 12

AS-70-230



84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

FIGURE 13

AS-70-231

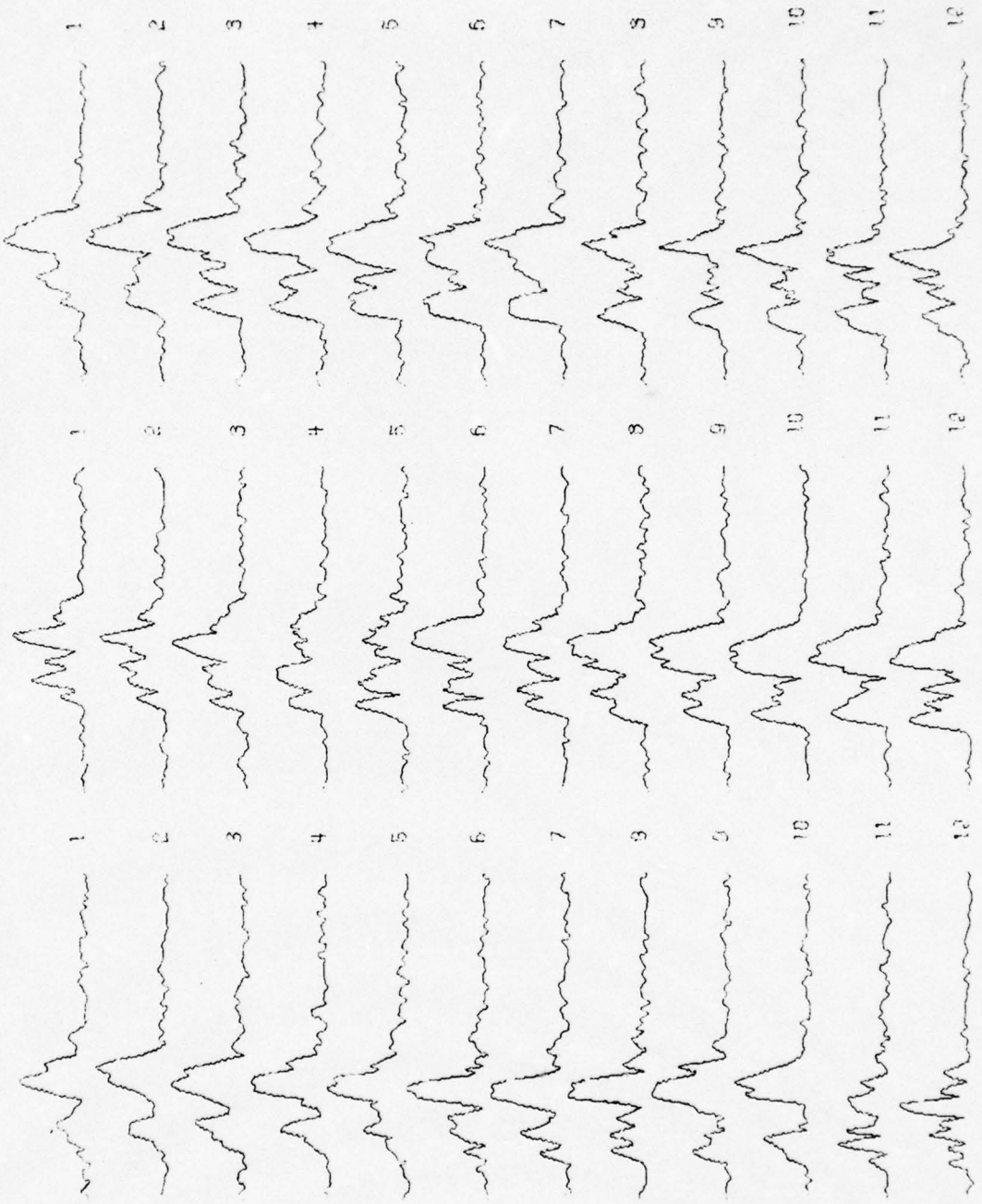


FIGURE 14

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-232

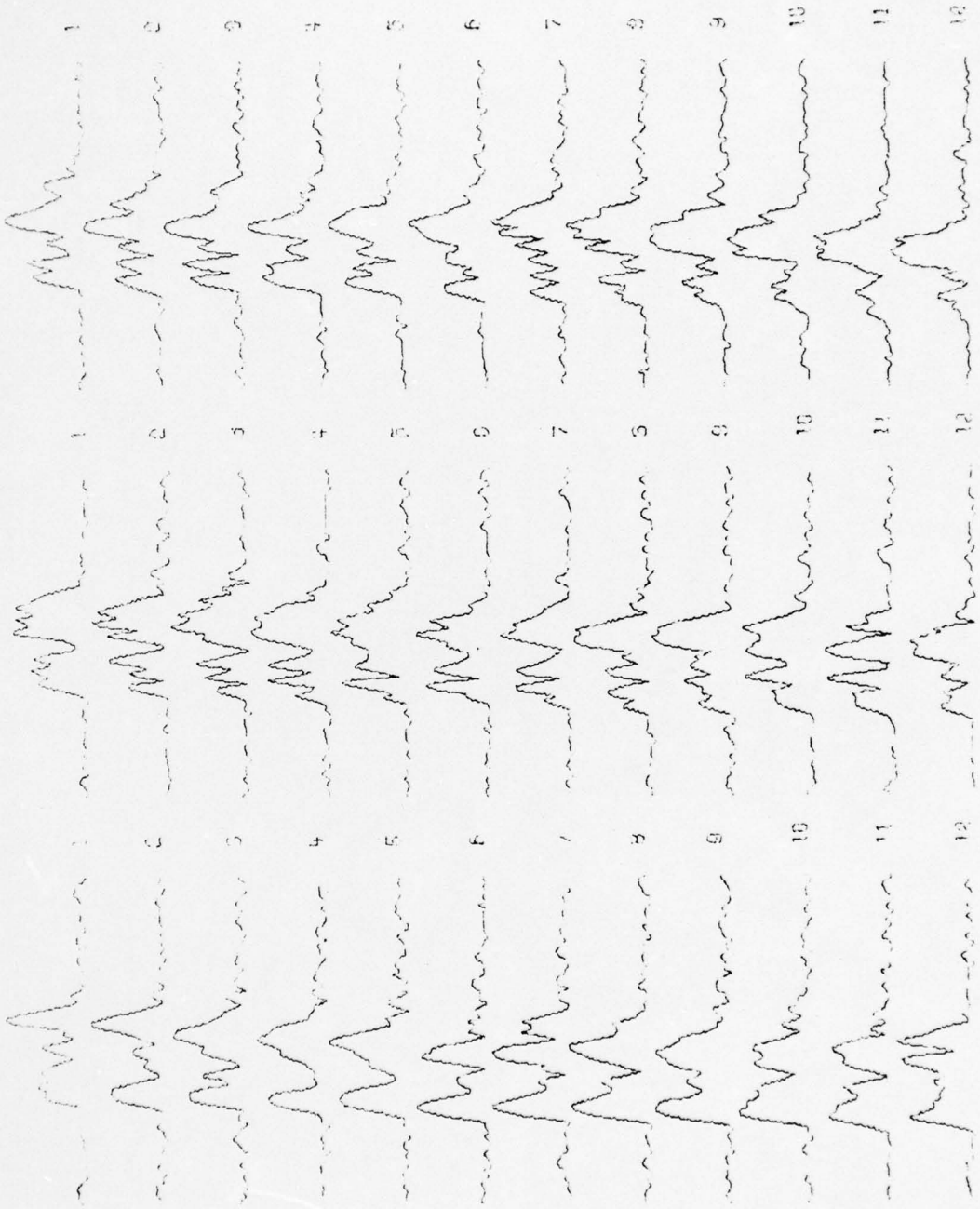


FIGURE 15

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-233

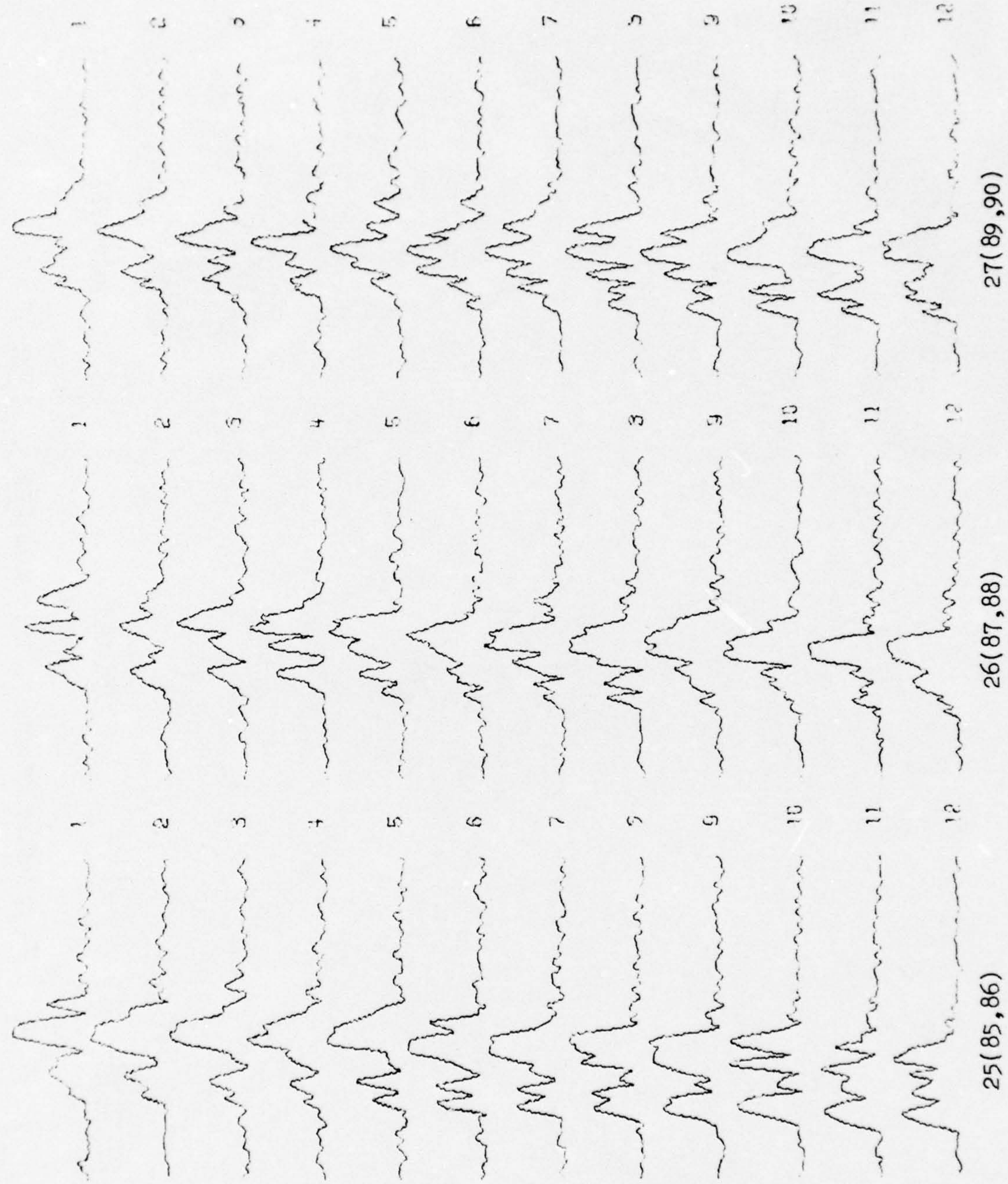
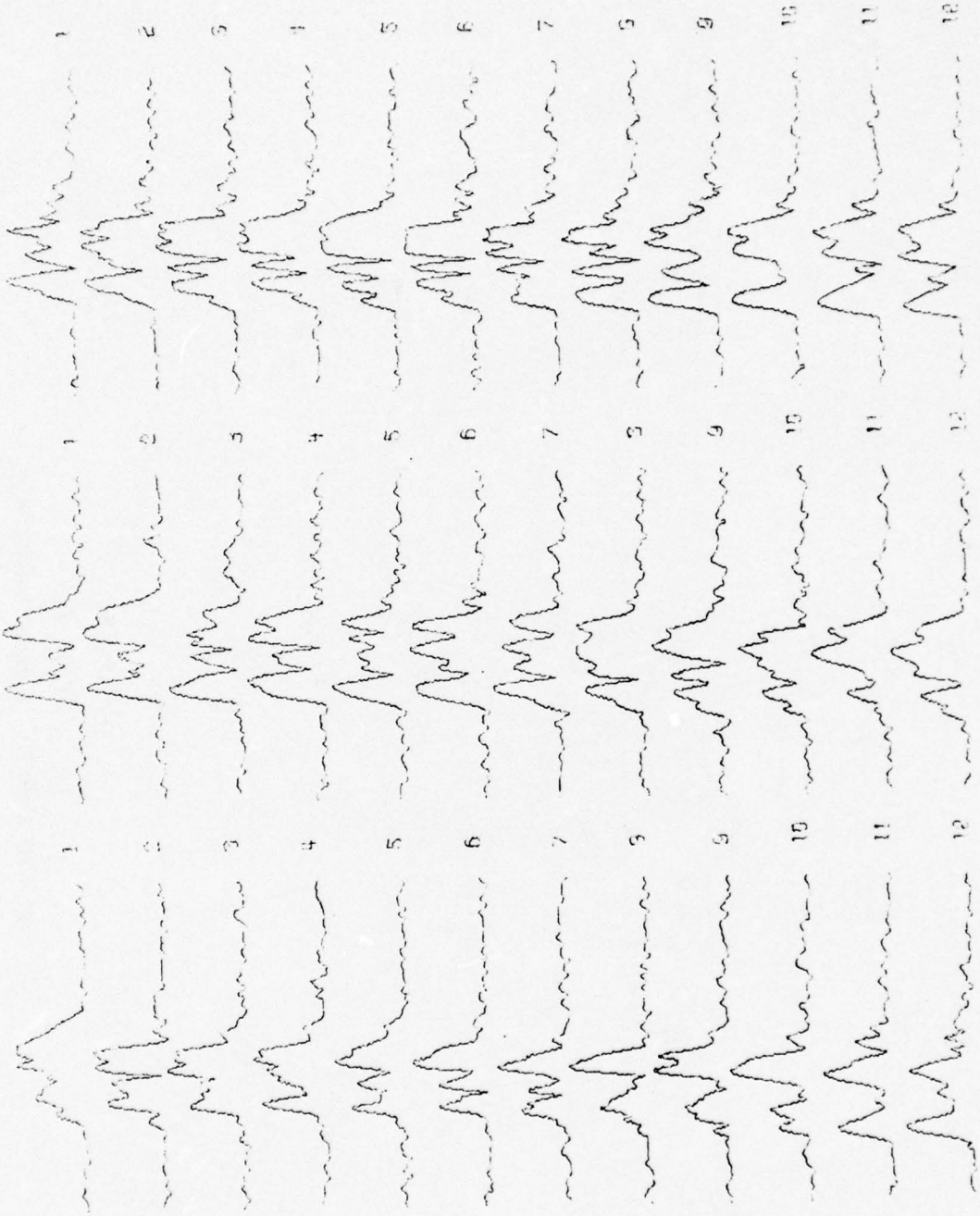


FIGURE 16

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-234



84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

FIGURE 17

AS-70-235

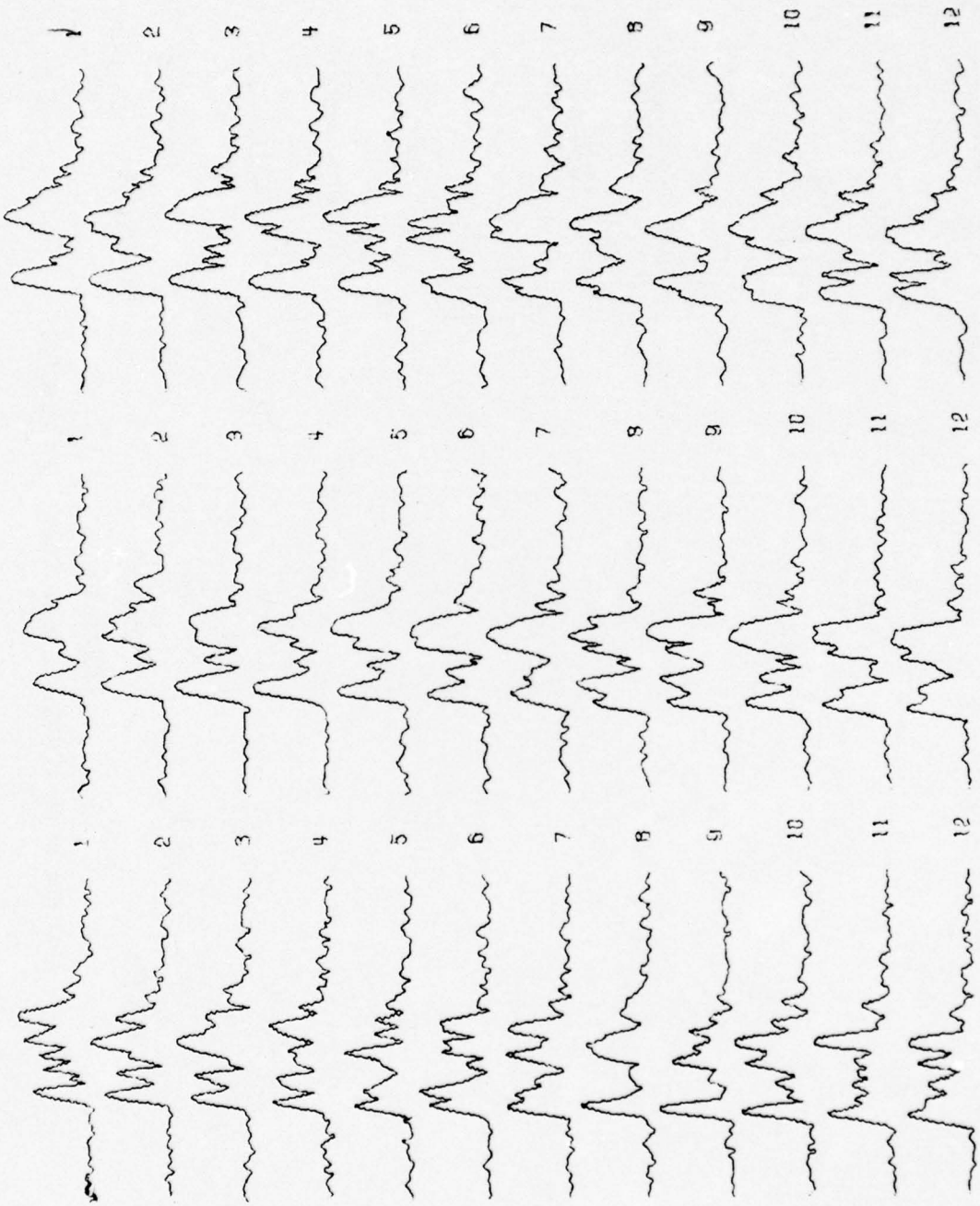


FIGURE 18

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-236

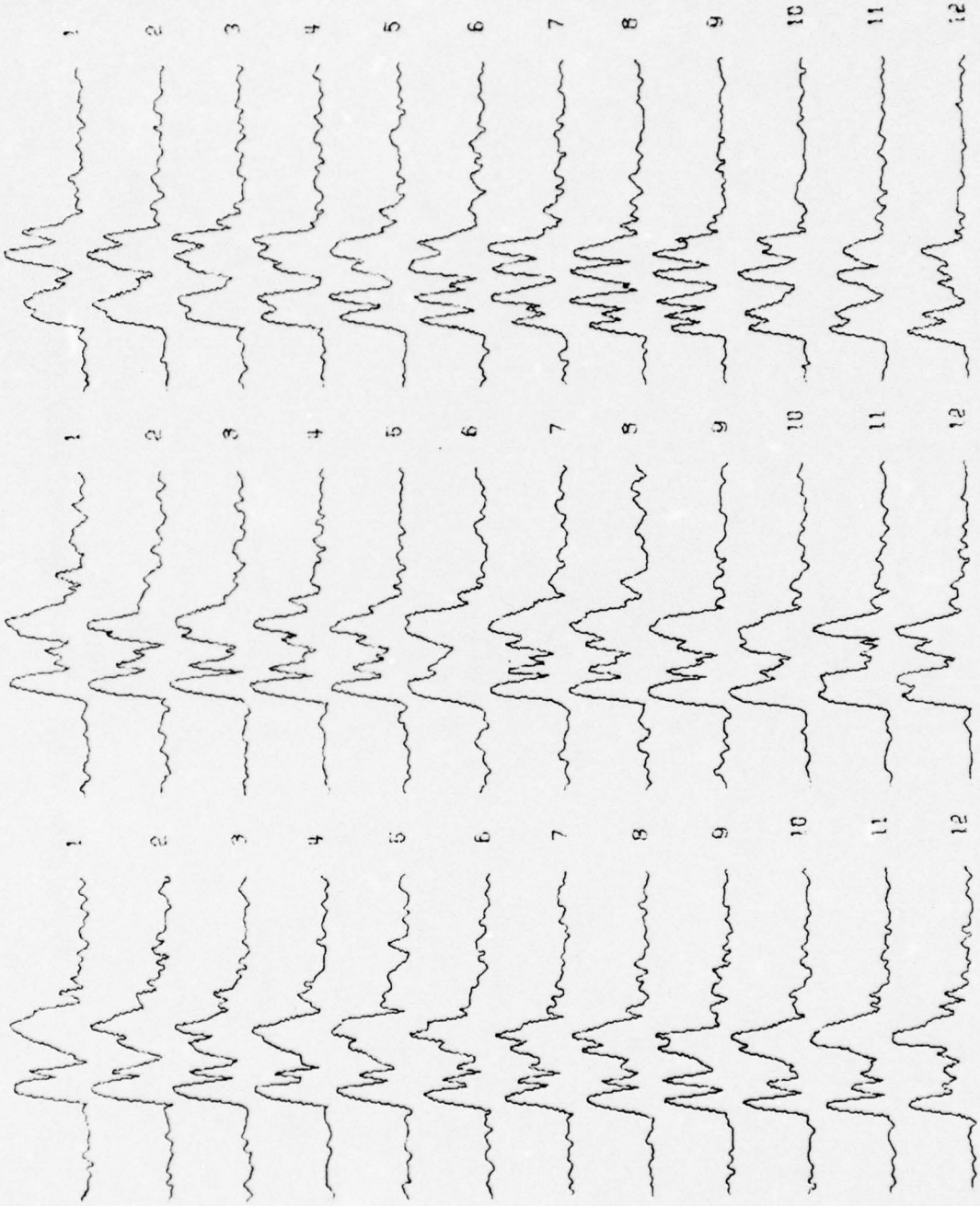


FIGURE 19

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-237

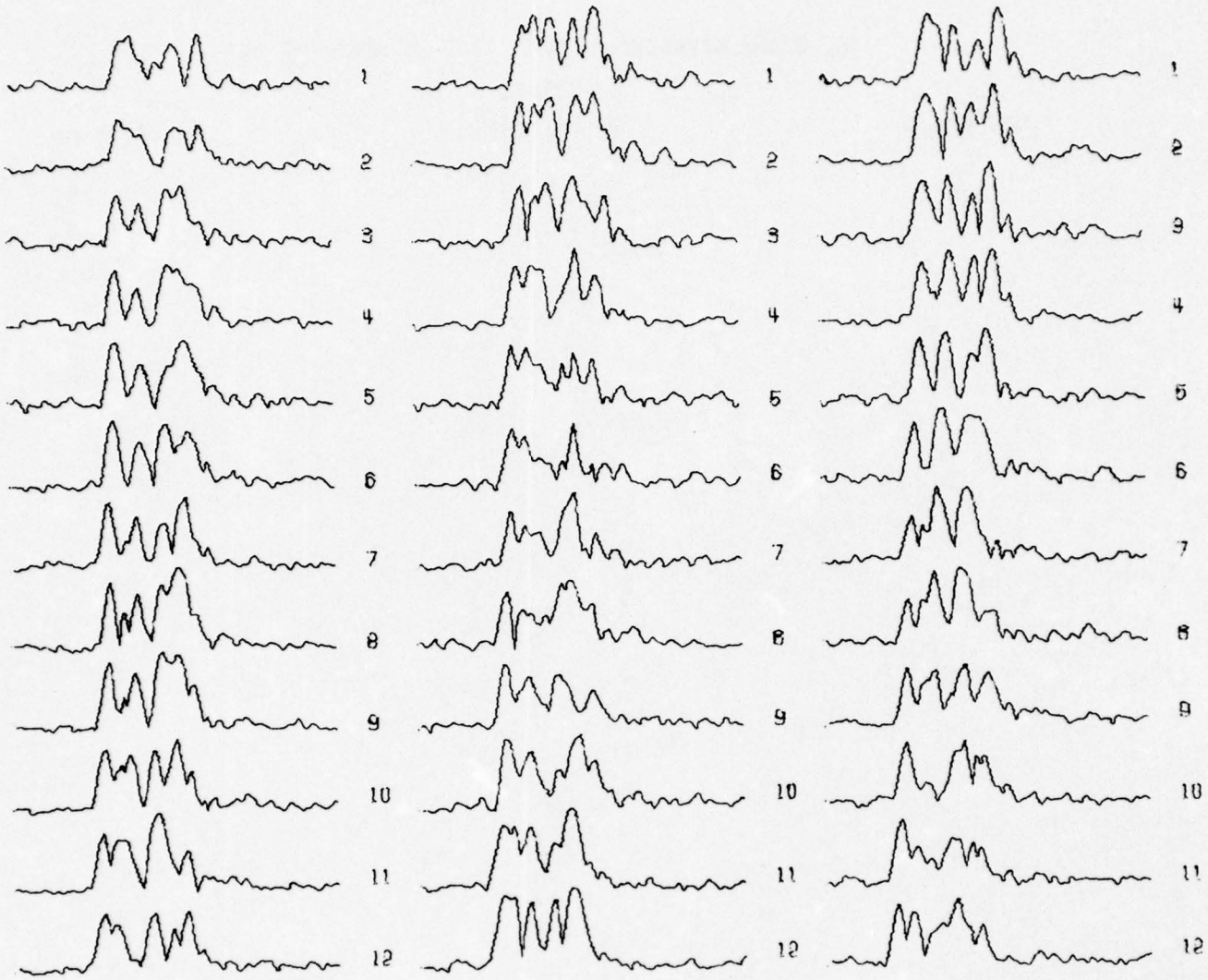


FIGURE 20

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

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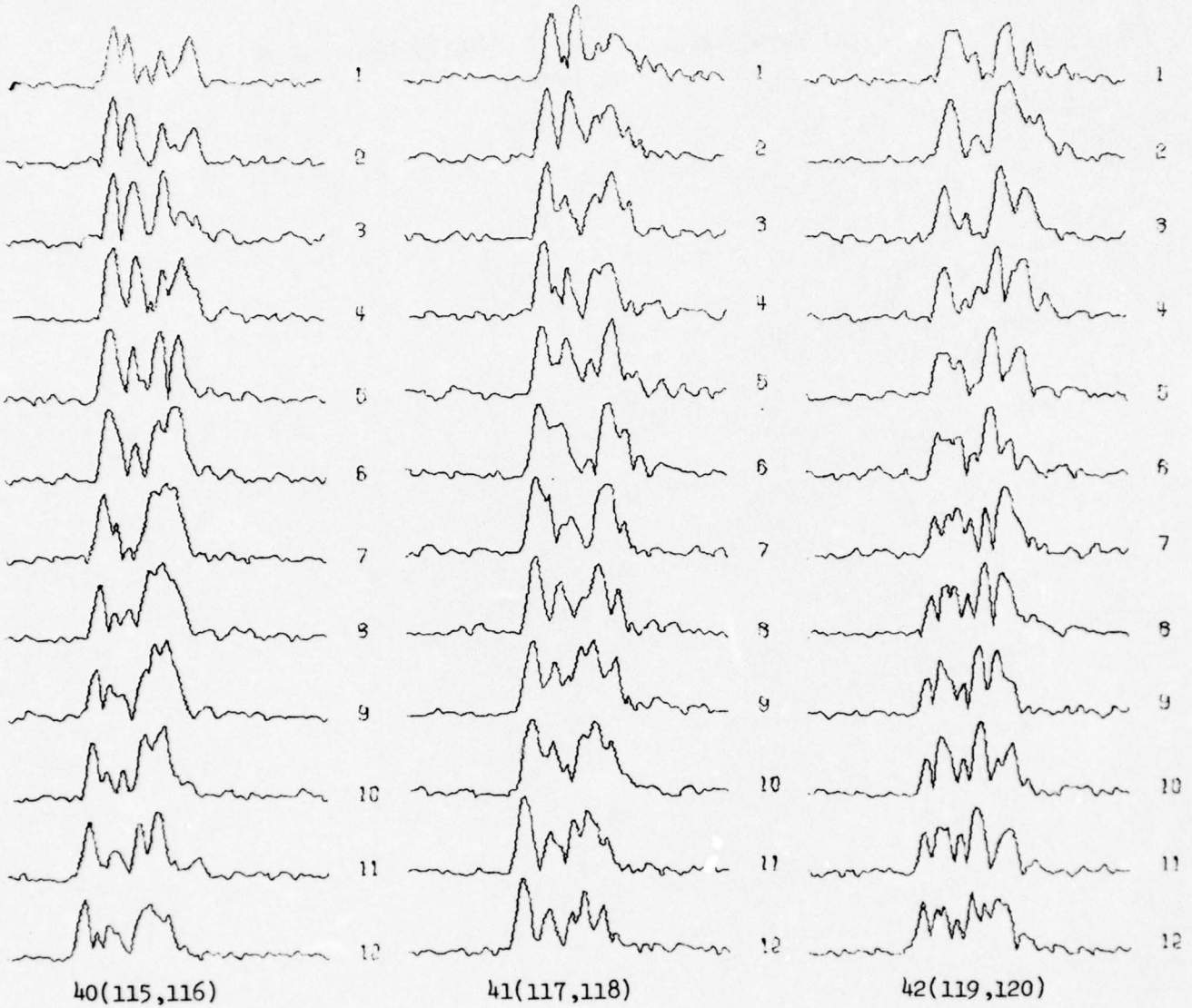

FIGURE 21

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

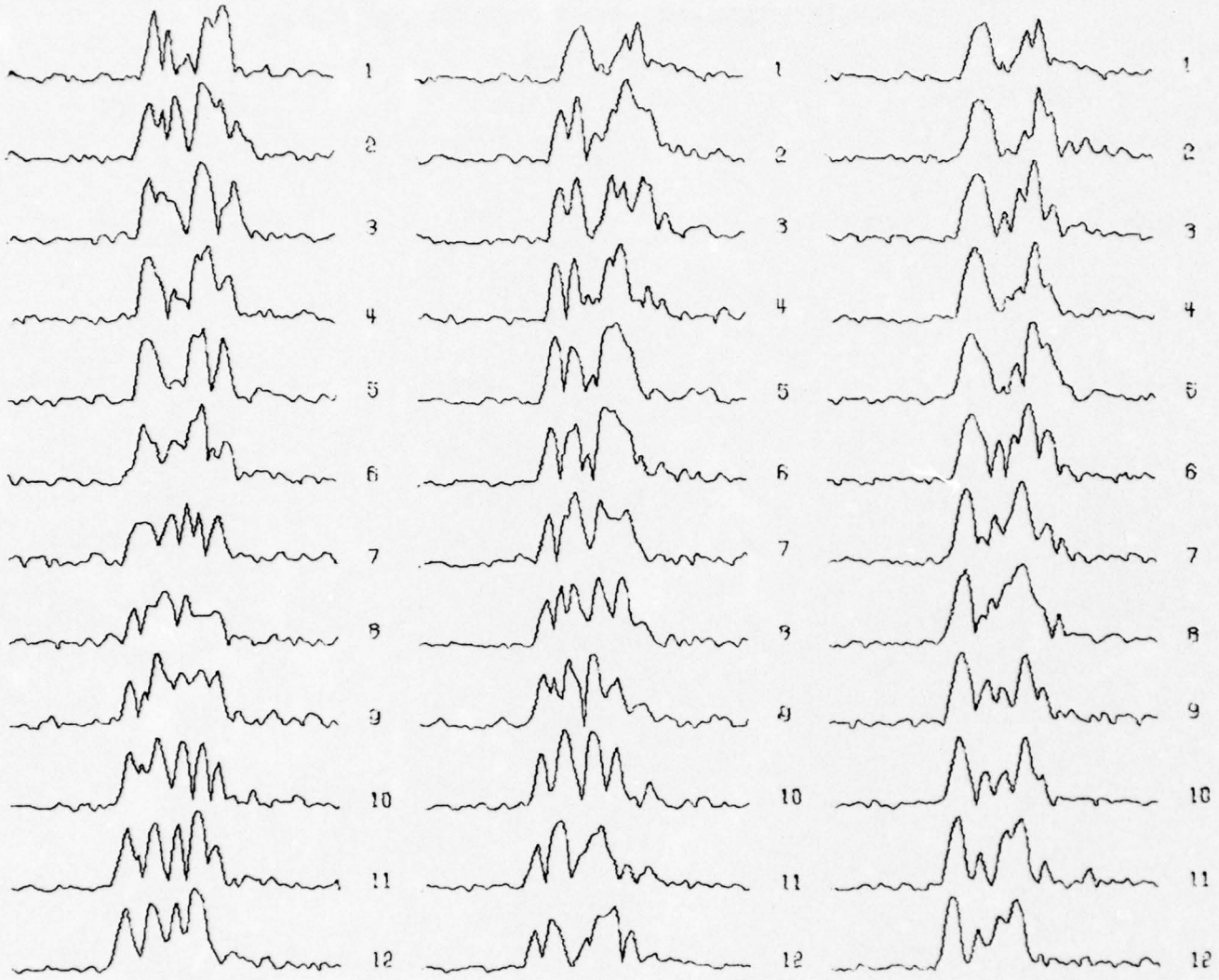

FIGURE 22

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

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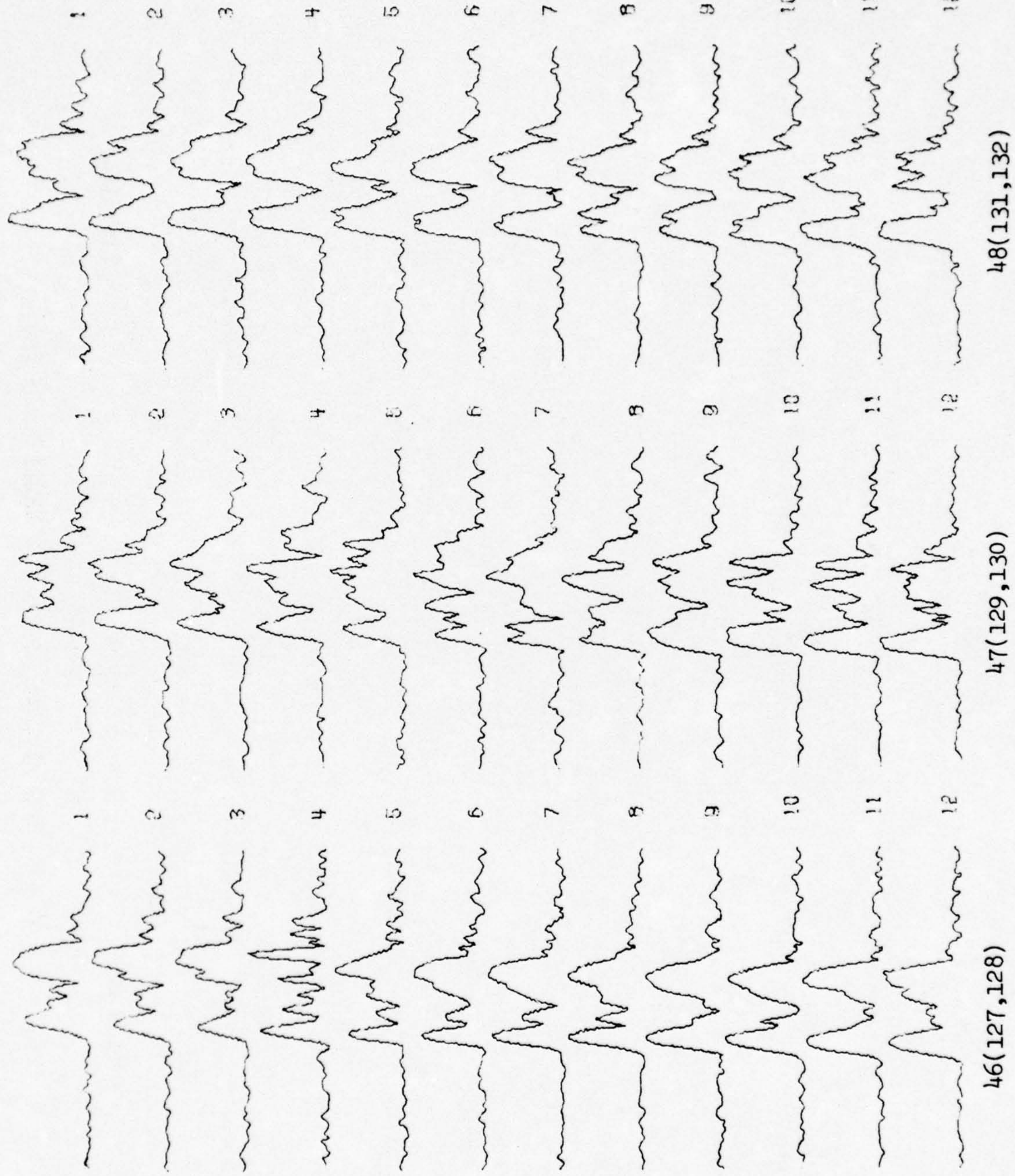

FIGURE 23

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-241

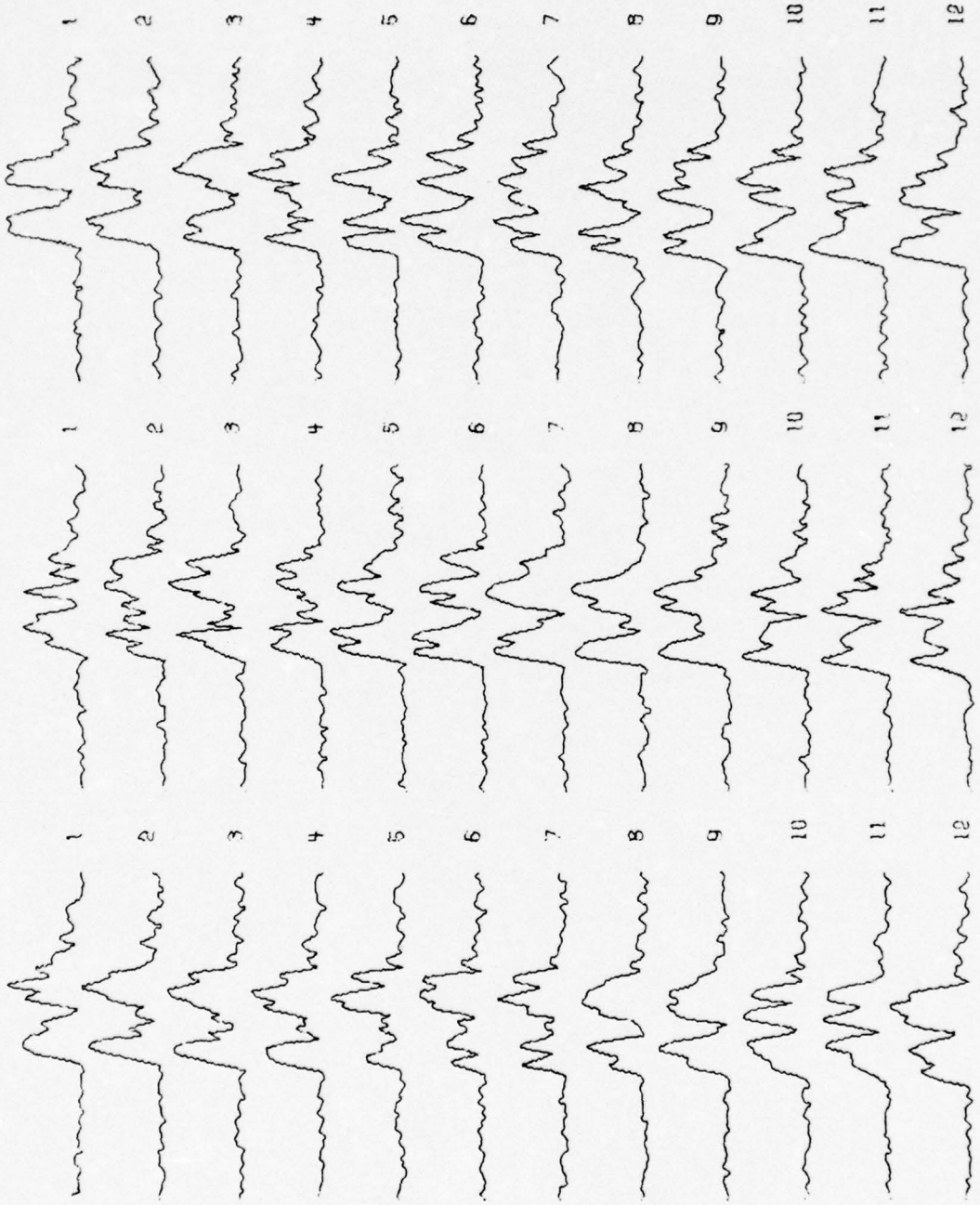

FIGURE 24

84 deg BEAM ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-242

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2. Group B: 1, 2, and 5 msec Transmit Pulse

(C) The echoes of Group B are from a submarine having a target aspect angle of 77 deg relative to stern. The destroyer and submarine had parallel courses, a range of 3900 yd, and speeds of 3 kt each.

(C) The analog data were sampled directly with a sampling rate of $4f_o$ = 20,000 samples per second. The digital data are stored on ARL computer tape 646. Each record, which contains one echo, on tape 646 is 3000 samples long. The computer plots are 1000 samples = 50 msec long. Tables IV, V, VI, and VII list the first sample number of each plot (IFROM). The last sample number of each plot (ITO) is obtained by adding 1000 to that plot's IFROM. For example the plot of the third echo of Echo Set 1 has an IFROM of 1804 and an ITO of 1804 + 1000 = 2804. Also these data are from record 3 (Rec. No. 3) of ARL computer tape 646. As another example, note that the sixth echo of Set 3 is found in record 31 of tape 646. The IFROM and ITO of the corresponding plot are 1348 and 2348, respectively. The first five sets of echoes (Sets 1, 2, 3, 4, and 5) correspond to the 1 msec transmit pulse, the second five sets (Sets 6, 7, 8, 9, and 10) to the 2 msec transmit pulse, and the last five sets (Sets 11, 12, 13, 14, and 15) to the 5 msec transmit pulse. The plots are given in Figs. 25 through 29.

TABLE IV

Group B; Beam Aspect; SARSFIELD Reel 33
12 Pings/Burst; Computer Tape 646
1 Set of 12 Echoes (U)

ITO = IFROM + 1000

(C)

Set 1, 1 msec		Set 2, 1 msec		Set 3, 1 msec		Set 4, 1 msec	
Rec. No.	IFROM	Rec. No.	IFROM	Rec. No.	IFROM	Rec. No.	IFROM
1	844	13	656	26	768	38	636
2	1332	14	1136	27	1252	39	1120
3	1804	15	1620	28	1740	40	1600
4	1792	16	1608	29	1720	41	1584
5	572	17	736	30	872	42	860
6	1060	18	1216	31	1348	43	1340
7	1540	19	1692	32	1828	44	1816
8	1520	20	1676	33	1812	45	1796
9	376	21	536	34	140	46	172
10	864	22	1020	35	616	47	652
11	1344	23	1500	36	1096	48	1132
12	1328	24	1476	37	1084	49	1112

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TABLE V

Group B

ITO = IFROM + 1000 (U)

(C)

Set 5, 1 msec		Set 6, 2 msec		Set 7, 2 msec		Set 8, 2 msec	
Rec. No.	IFROM	Rec. No.	IFROM	Rec. No.	IFROM	Rec. No.	IFROM
50	700	62	360	74	428	86	804
51	1184	63	844	75	908	87	1284
52	1668	64	1328	76	1388	88	1768
53	1652	65	1308	77	1368	89	1748
54	996	66	400	78	520	90	632
55	1472	67	888	79	1004	91	1116
56	1952	68	1358	80	1488	92	1600
57	1932	69	1348	81	1464	93	1580
58	280	70	644	82	584	94	668
59	756	71	1124	83	1064	95	1148
60	1240	72	1604	84	1544	96	1632
61	1220	73	1592	85	1520	97	1612

TABLE VI

Group B

ITO = IFROM + 1000 (U)

(C)

Set 9, 2 msec		Set 10, 2 msec		Set 11, 5 msec		Set 12, 5 msec	
Rec. No.	IFROM	Rec. No.	IFROM	Rec. No.	IFROM	Rec. No.	IFROM
98	668	110	532	122	576	134	592
99	1144	111	1020	123	1072	135	1080
100	1632	112	1504	124	1540	136	1556
101	1616	113	1488	125	1550	137	1530
102	760	114	868	126	192	138	532
103	1240	115	1344	127	672	139	1000
104	1716	116	1820	128	1140	140	1474
105	1700	117	1804	129	1112	141	1444
106	812	118	288	130	1068	142	1094
107	1292	119	768	131	1564	143	1558
108	1780	120	1252	132	2044	144	2024
109	1768	121	1232	133	2020	145	2010

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TABLE VII

Group B

ITO = IFROM + 1000 (U)

(C)

Set 13, 5 msec		Set 14, 5 msec		Set 15, 5 msec	
Rec. No.	IFROM	Rec. No.	IFROM	Rec. No.	IFROM
146	628	158	644	170	600
147	1112	159	1126	171	1060
148	1578	160	1572	172	1544
149	1564	161	1556	173	1536
150	484	162	452	174	500
151	980	163	920	175	972
152	1460	164	1400	176	1452
153	1432	165	1372	177	1432
154	996	166	968	178	40
155	1468	167	1444	179	516
156	1960	168	1968	180	980
157	1916	169	1888	181	956

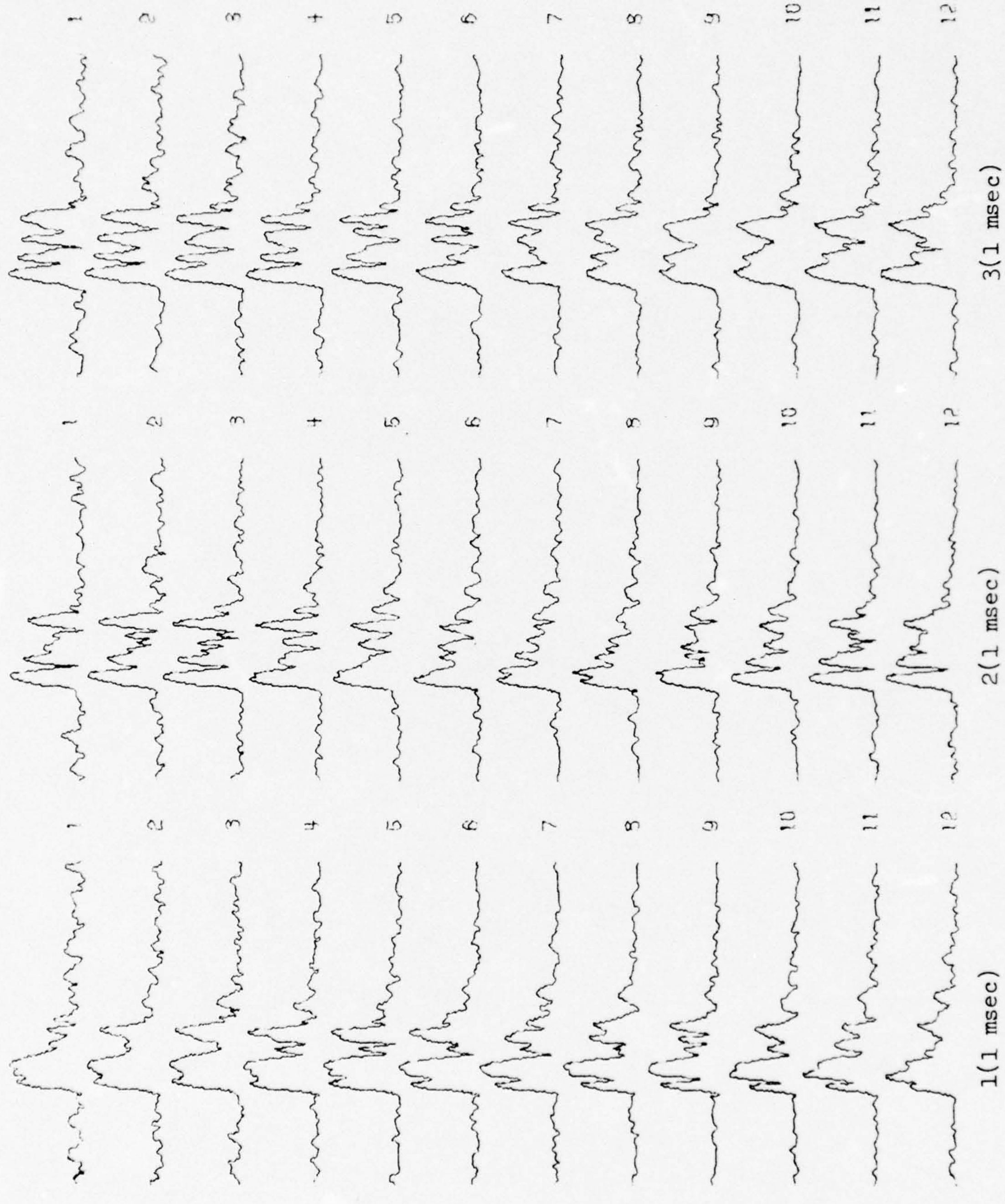

FIGURE 25

77 deg BEAM ASPECT (U)

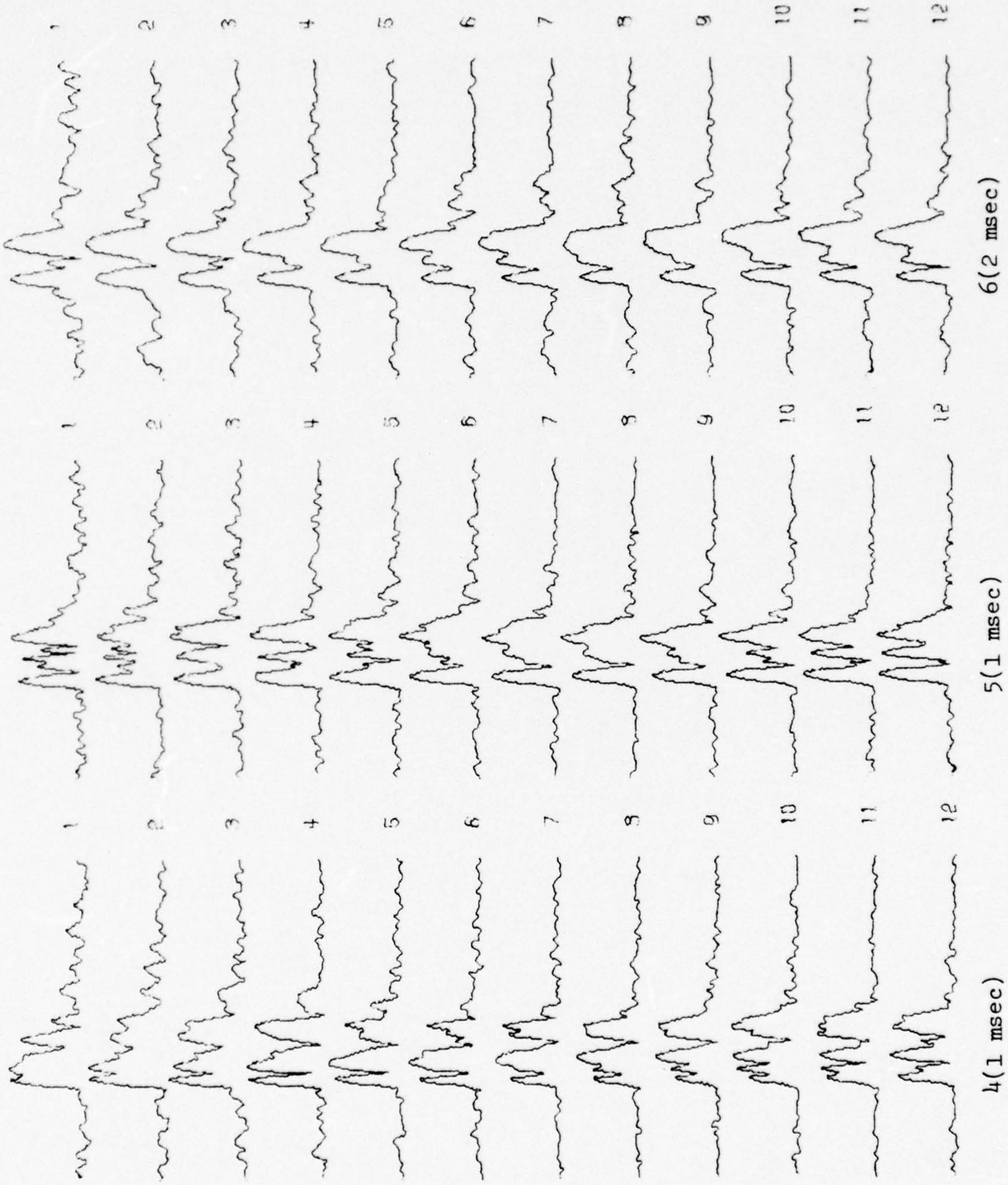

FIGURE 26

77 deg BEAM ASPECT (U)

AS-70-244

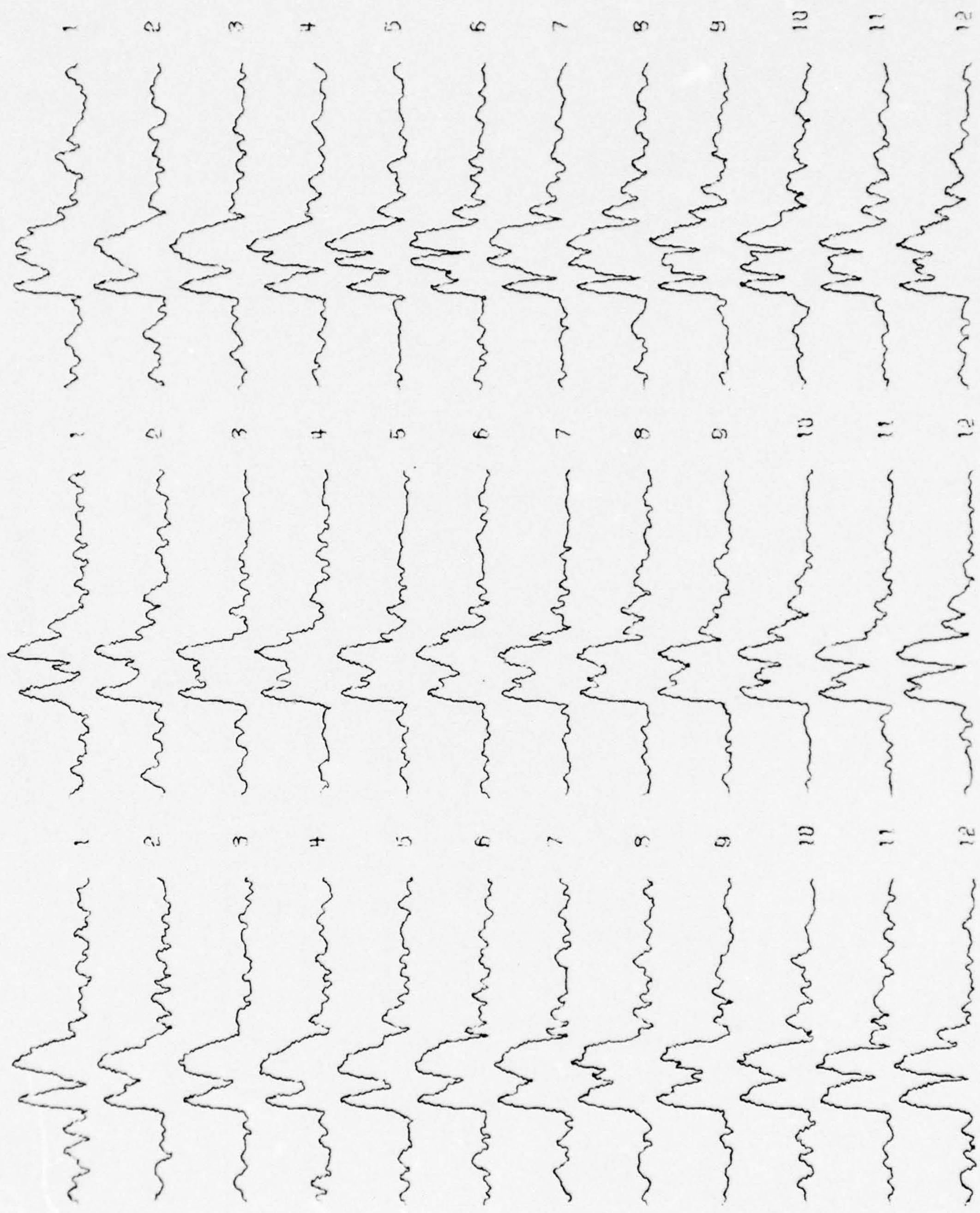

FIGURE 27

77 deg BEAM ASPECT (U)

AS-70-245

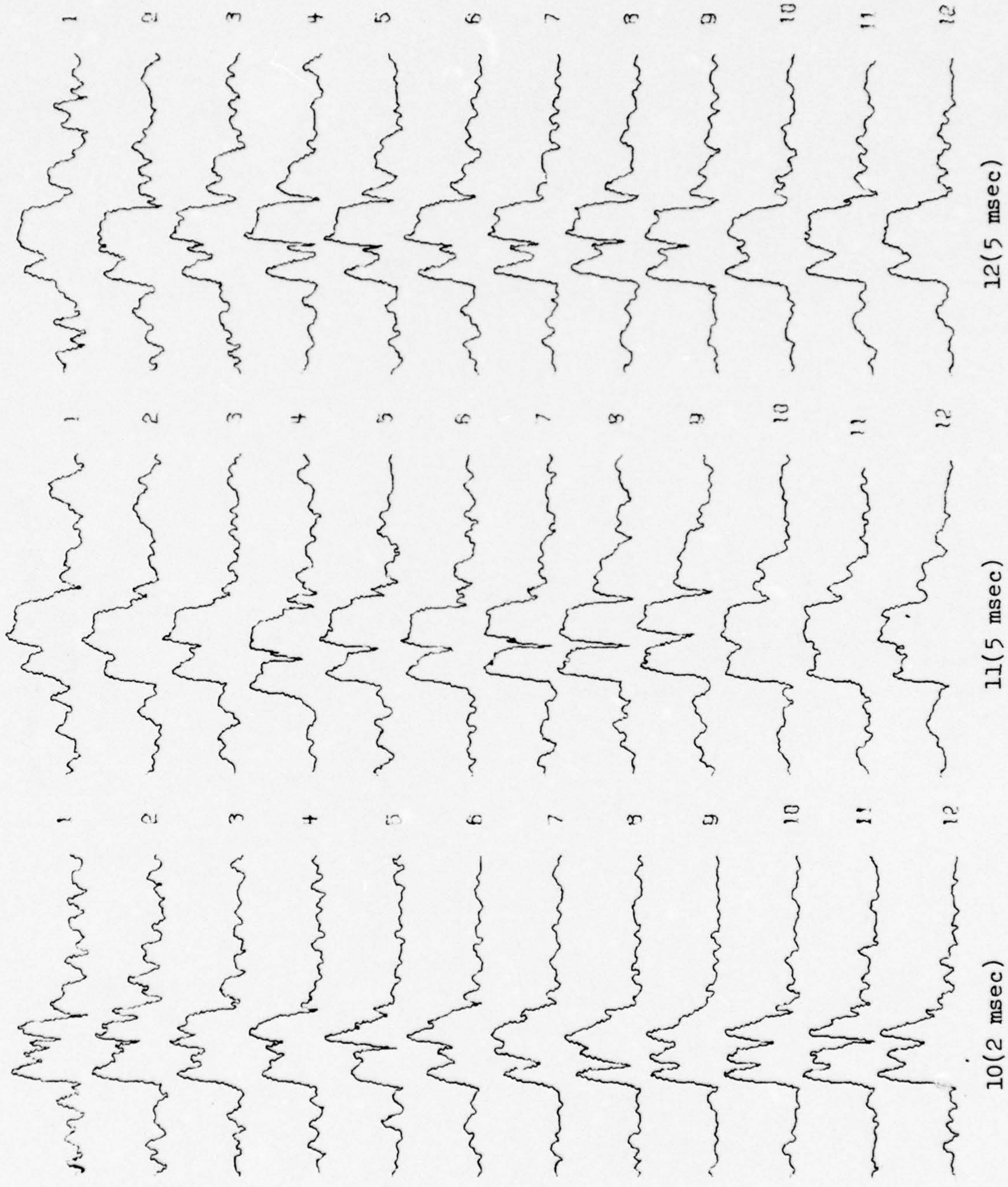

FIGURE 28

77 deg BEAM ASPECT (U)

AS-70-246

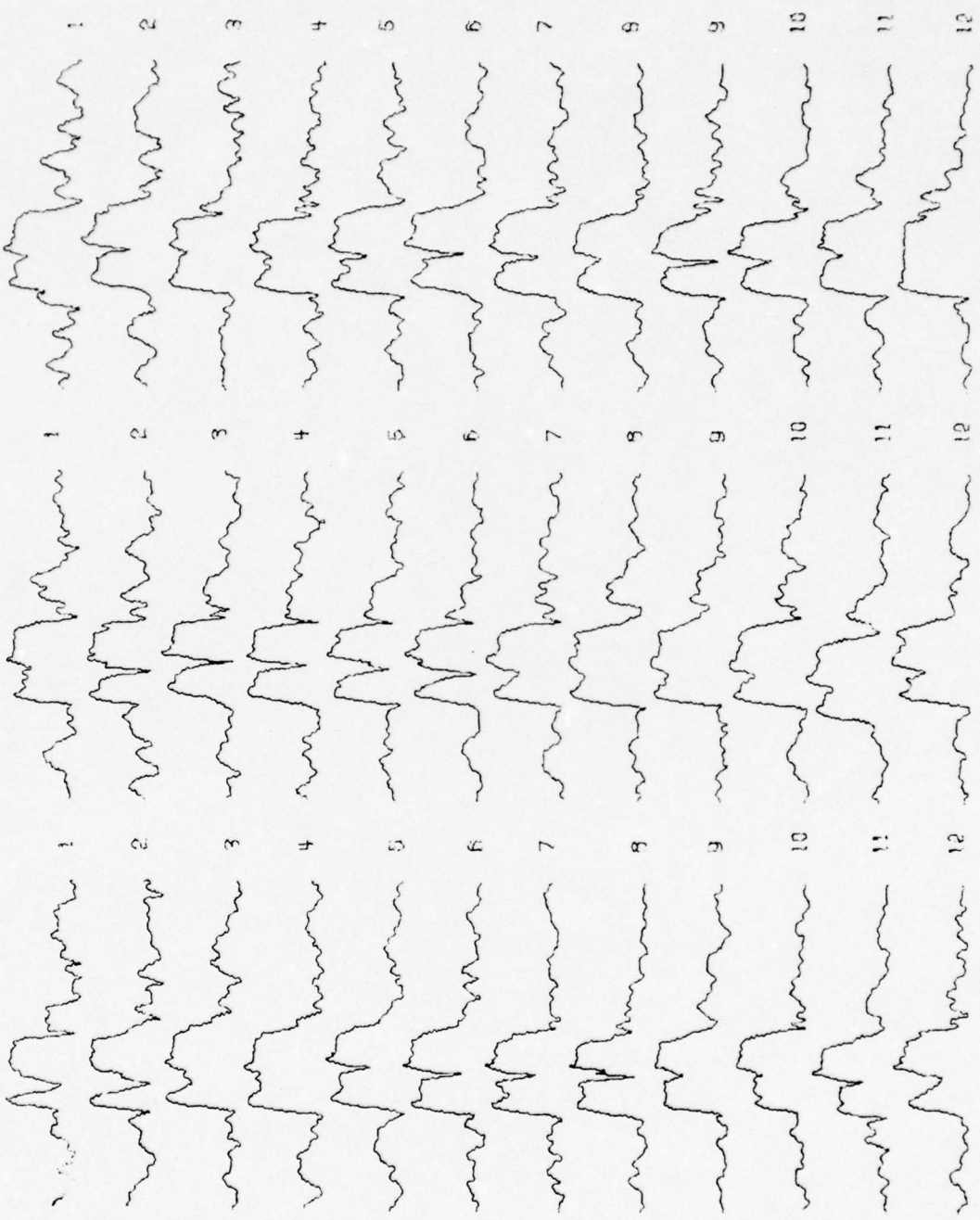

FIGURE 29

77 deg BEAM ASPECT (U)

AS-70-247

B. Stern Aspect Submarine Echoes: 5 msec Transmit Pulse

(C) This collection of data was generated by a submarine with an aspect of 20 deg relative to stern. The transmit pulse length was 5 msec. The analog echoes were sampled directly with a sampling rate of $4f_o$ = 20 kHz. Nine echo sets, each set containing 12 echoes, are plotted and the IFROMs and ITOs of these plots are listed in Tables VIII, IX, and X. These data can be found on ARL computer tape 648. Each record of this tape is 4000 samples long and contains one echo. The epoch of the echo was estimated to be 2440 samples = 122 msec long. The following plots contain a 100-sample interval preceding the beginning of the echo and a 100-sample interval following the echo. Thus each plot has a length of 2440 + 200 = 2640 samples = 132 msec. Figures 30 through 32 give the individual echo plots.

TABLE VIII

Group II; Stern Aspect; SARSFIELD Reel 39
12 Pings/Burst; Computer Tape 648, 20 kHz Sample Rate
1 Ensemble of 12 Echoes, ~116 msec (U)

5 msec Transmit Pulse

(C)

SET 1			SET 2			SET 3		
Rec. No.	IFROM	ITO	Rec. No.	IFROM	ITO	Rec. No.	IFROM	ITO
1	712	3352	13	712	3352	25	692	3332
2	692	3332	14	692	3332	26	644	3284
3	680	3320	15	704	3340	27	632	3272
4	408	3048	16	432	3072	28	392	3032
5	388	3028	17	384	3024	29	380	3020
6	376	3016	18	356	2996	30	368	3008
7	268	2908	19	280	2920	31	236	2876
8	252	2892	20	276	2916	32	220	2860
9	296	2936	21	256	2896	33	208	2848
10	560	3200	22	576	3216	34	508	3148
11	552	3192	23	572	3212	35	496	3136
12	496	3136	24	564	3204	36	484	3134

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TABLE IX

Stern Aspect: Computer Plots' IFROM, ITO (U)

5 msec Transmit Pulse

(C)

SET 4			SET 5			SET 6		
Rec. No.	IFROM	ITO	Rec. No.	IFROM	ITO	Rec. No.	IFROM	ITO
37	632	3272	49	684	3324	61	716	3356
38	616	3256	50	676	3316	62	708	3348
39	600	3240	51	660	3300	63	680	3320
40	400	3040	52	436	3076	64	508	3148
41	388	3028	53	420	3060	65	472	3112
42	368	3008	54	412	3052	66	460	3100
43	272	2912	55	284	2924	67	380	3020
44	264	2904	56	272	2912	68	360	3000
45	248	2888	57	264	2904	69	356	2996
46	560	3200	58	552	3192	70	628	3288
47	548	3188	59	544	3184	71	620	3280
48	536	3176	60	588	3228	72	608	3248

TABLE X

Stern Aspect: Computer Plots' IFROM, ITO (U)

5 msec Transmit Pulse

(C)

SET 7			SET 8			SET 9		
Rec. No.	IFROM	ITO	Rec. No.	IFROM	ITO	Rec. No.	IFROM	ITO
73	732	3372	85	776	3416	97	852	3492
74	740	3380	86	764	3404	98	812	3452
75	720	3360	87	752	3392	99	808	3448
76	556	3196	88	548	3188	100	608	3248
77	544	3184	89	536	3176	101	604	3244
78	532	3172	90	532	3172	102	572	3212
79	400	3040	91	448	3088	103	508	3148
80	384	3024	92	440	3080	104	508	3148
81	368	3008	93	428	3068	105	516	3156
82	688	3328	94	688	3328	106	796	3436
83	672	3312	95	672	3312	107	792	3432
84	660	3300	96	668	3308	108	780	3420

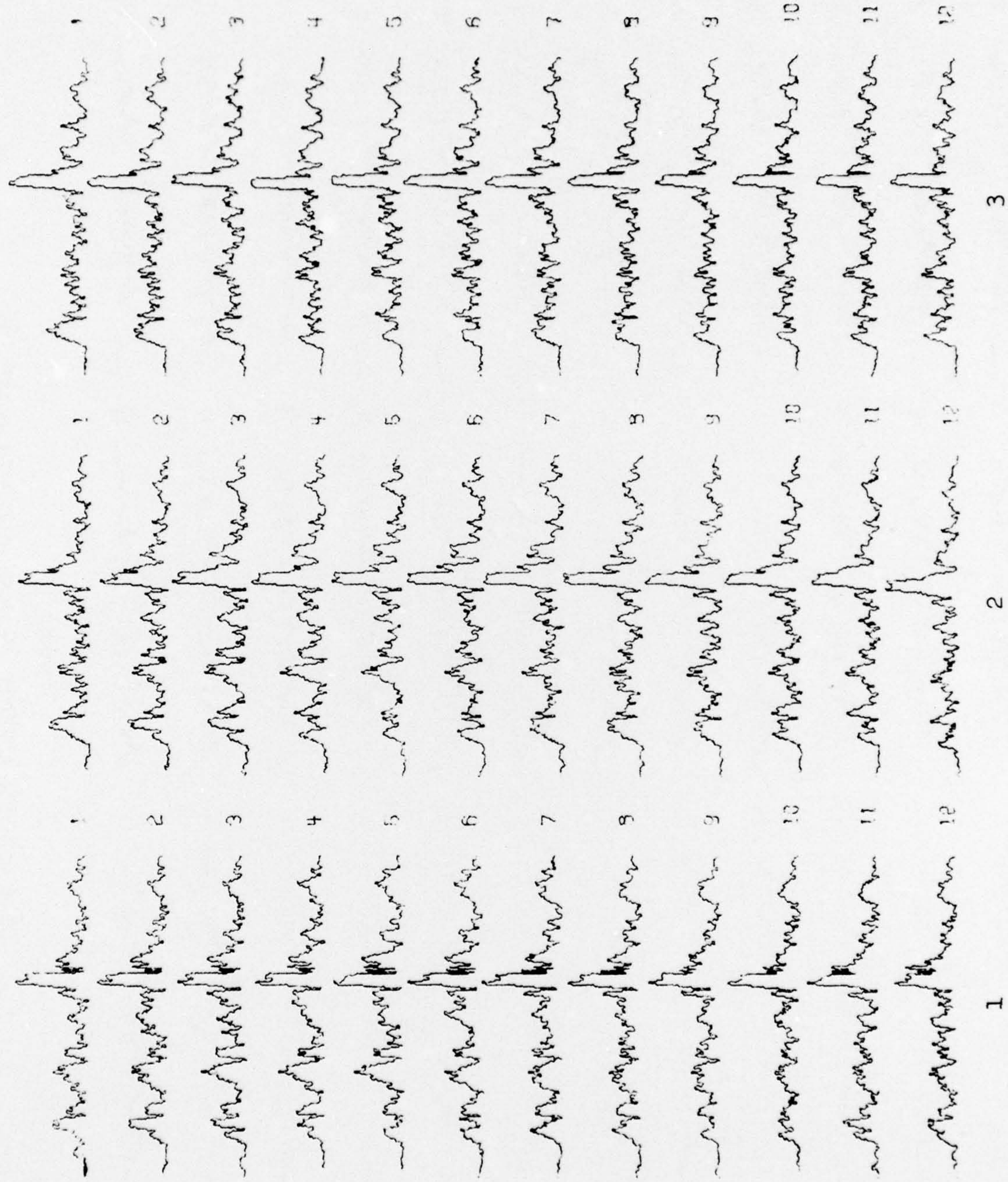

FIGURE 30

20 deg STERN ASPECT: 5 msec TRANSMIT PULSE (U)

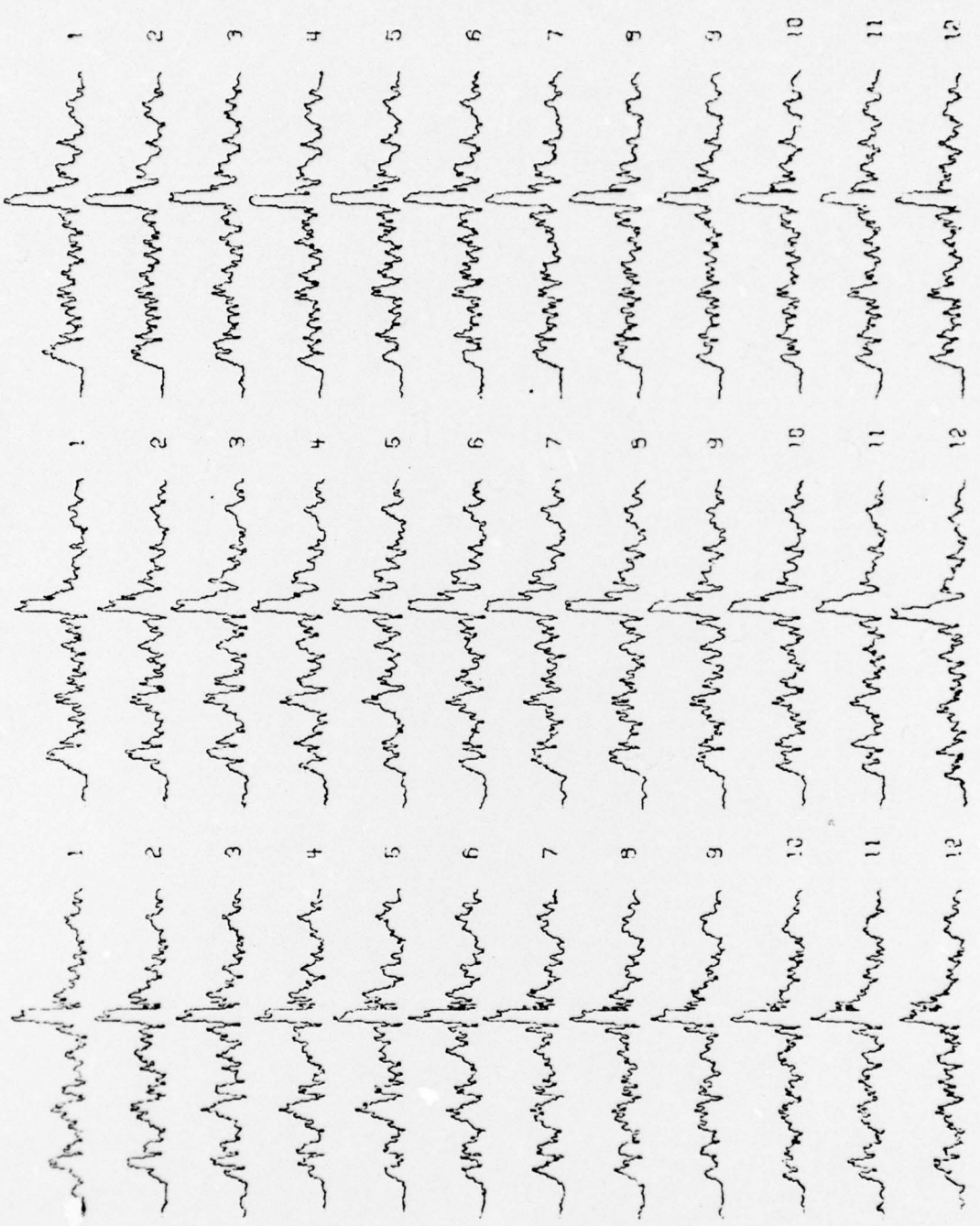

FIGURE 31

20 deg STERN ASPECT: 5 msec TRANSMIT PULSE (U)

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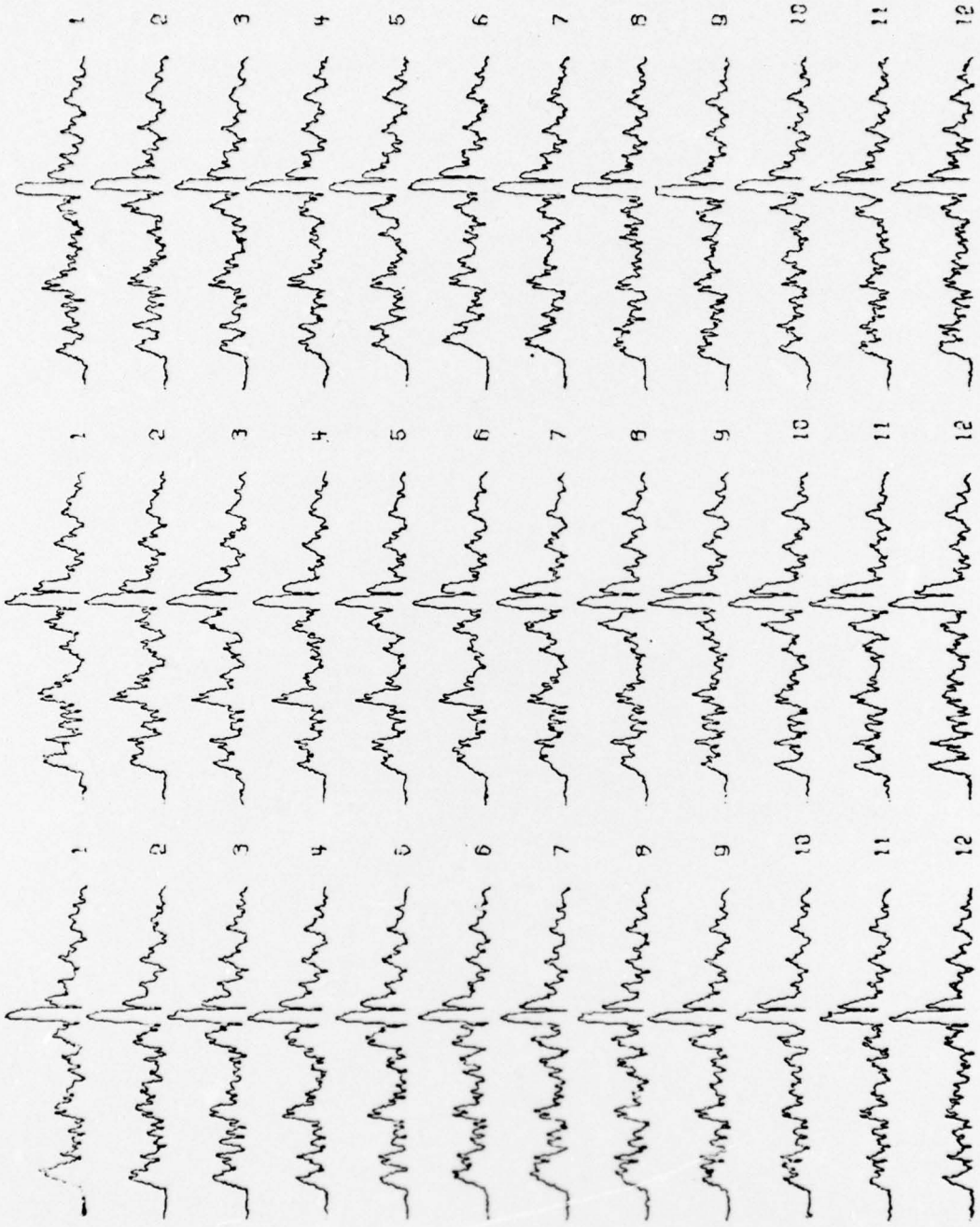

FIGURE 32

20 deg STERN ASPECT: 5 msec TRANSMIT PULSE (U)

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AS-70-250

C. Bow Aspect Submarine Echoes: 1 msec Transmit Pulse

(C) This is a collection of 11 sets of bow aspect echoes. Each set contains 12 echoes. The transmit pulse length was 1 msec. The quadrature components of the analog data were digitized, each component being sampled at a rate of 2500 samples per second. The range of the target was 4000 yd, although the exact target geometry that produced these data is unknown. However, it is very likely that the destroyer and submarine had a target aspect, as estimated from the echo epoch, of about 20 deg relative to bow.

(U-FOUO) Table XI gives the IFROM and ITO of the first plot of each set of 12 echoes. The $(IFROM)_n$ of the n^{th} echo of a set is given by

$$(IFROM)_n = IFROM + (n-1)(943) \quad .$$

Similarly the corresponding $(ITO)_n$ is given by

$$(ITO)_n = ITO + (n-1)(943) \quad .$$

Thus the IFROM and ITO of the eighth echo of the fifth echo set is

$$(IFROM)_8 = 1615 + (8-1)(943)$$

$$= 8116 \quad ,$$

and

$$(ITO)_8 = 1935 + (8-1)(943)$$

$$= 8436 \quad .$$

Each plot is 320 samples = 128 msec in length. The 11 sets, each set containing 12 echoes, are shown in Figs. 33 through 36.

TABLE XI

Bow Aspect: Computer Plots' IFROM, ITO (U)

(C) Rec. No.	IFROM	ITO
1	1600	1920
2	1598	1918
3	1601	1921
4	1610	1930
5	1615	1935
6	1619	1939
7	1626	1946
8	1633	1953
9	1640	1960
10	1644	1964
11	1646	1966

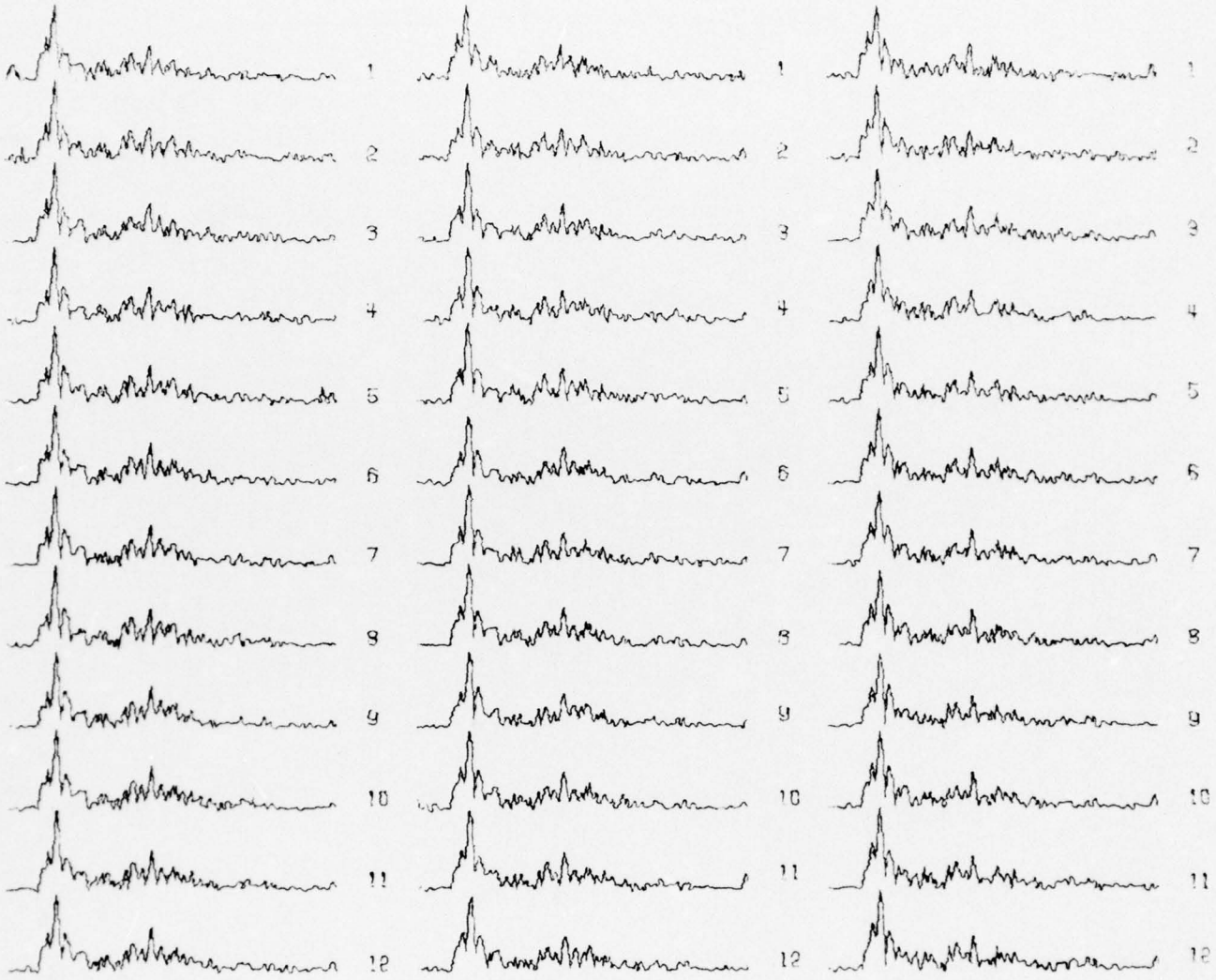

FIGURE 33

BOW ASPECT: 1 msec TRANSMIT PULSE (U)

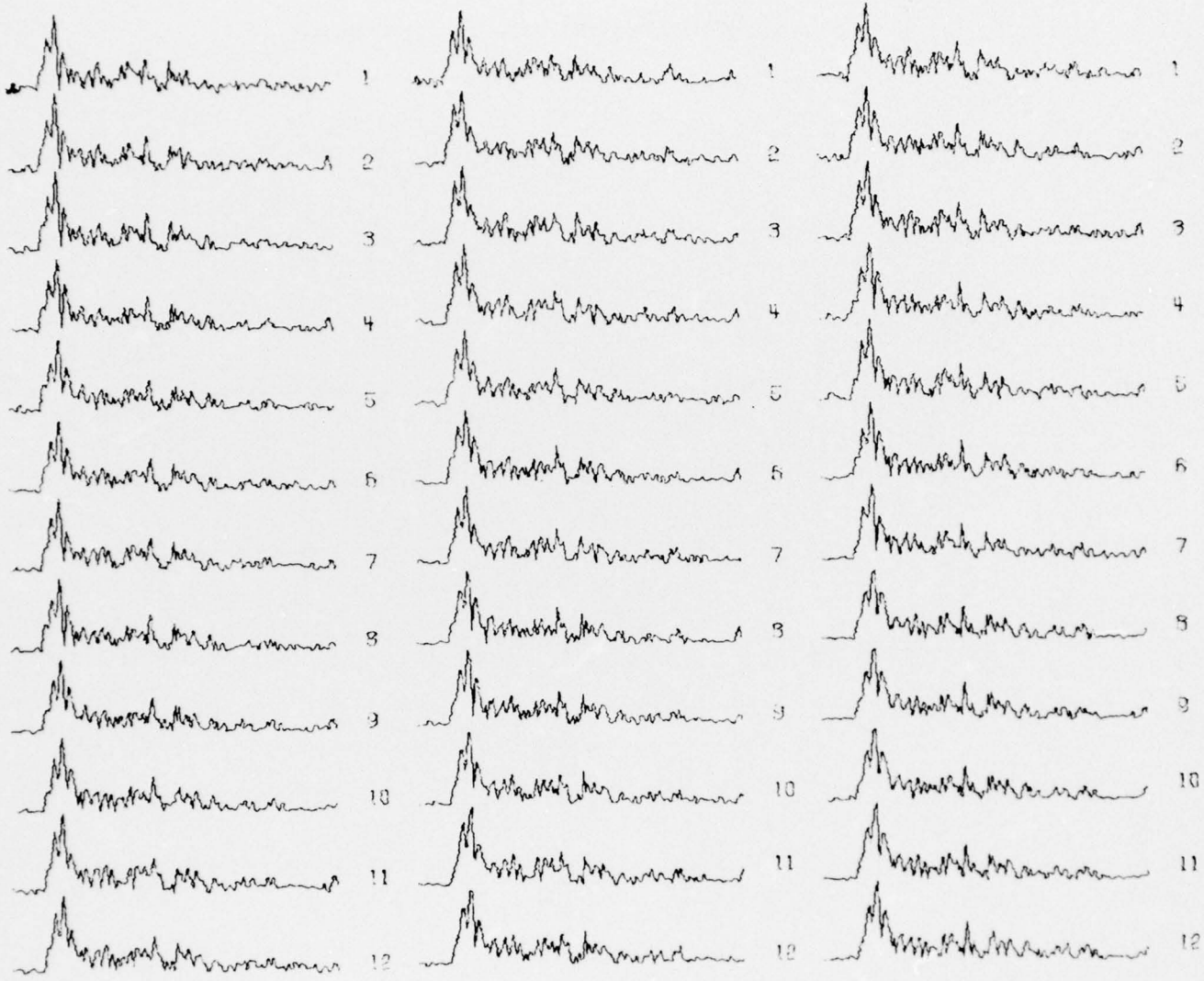

FIGURE 34

BOW ASPECT: 1 msec TRANSMIT PULSE (U)

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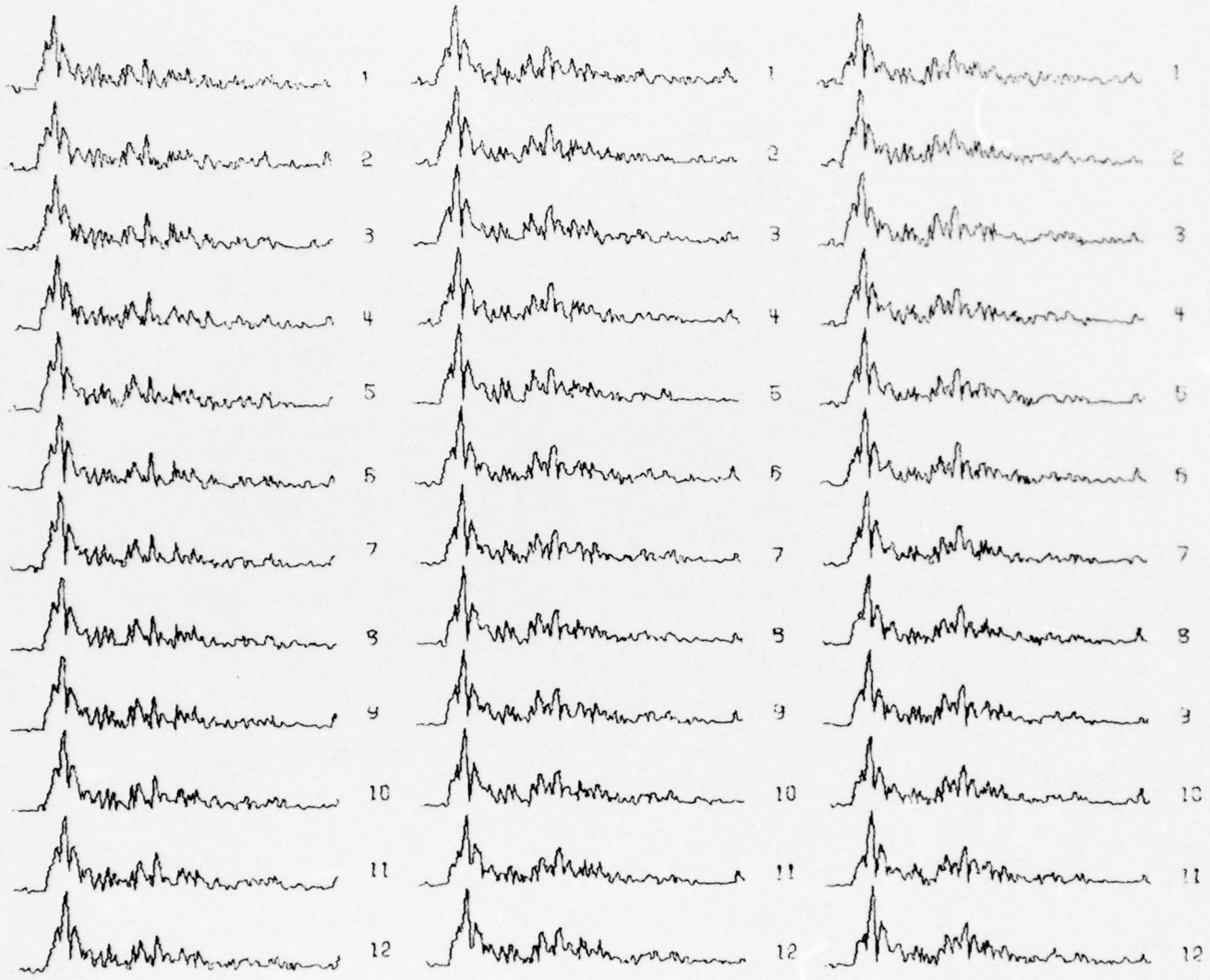

FIGURE 35

BOW ASPECT: 1 msec TRANSMIT PULSE (U)

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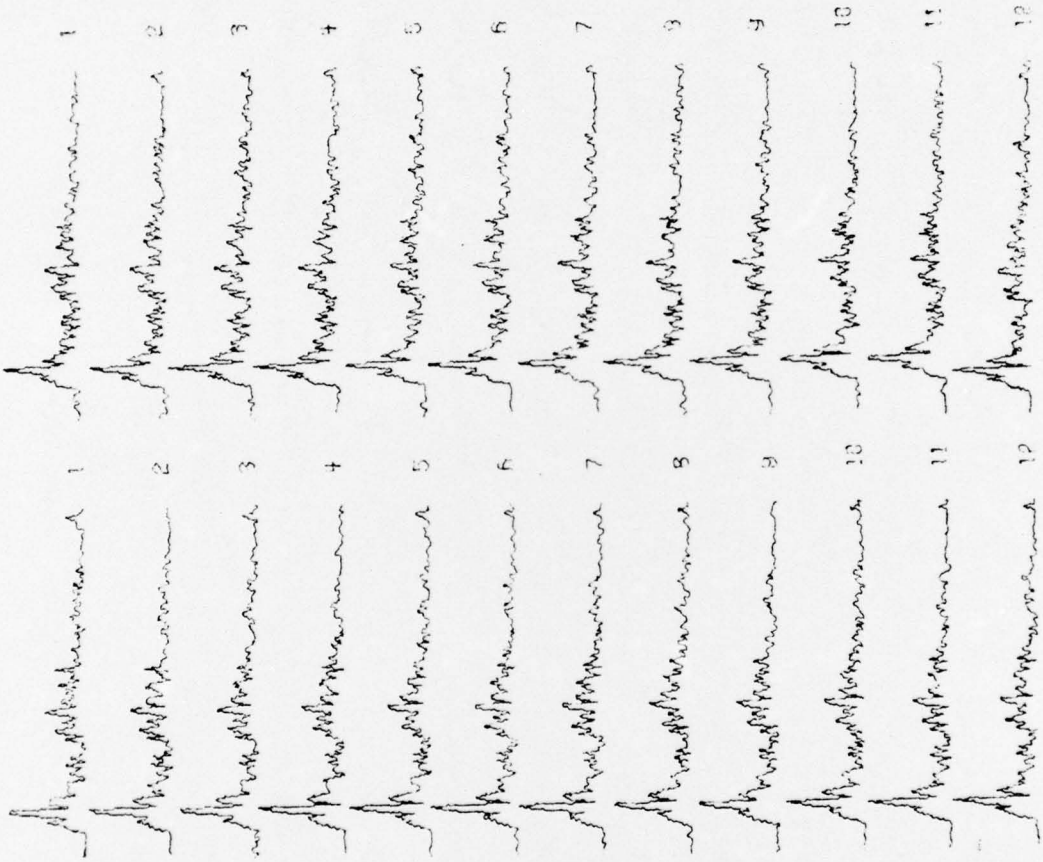

10(19,20) 11(21,22)

FIGURE 36

BOW ASPECT: 1 msec TRANSMIT PULSE (U)

AS-70-254

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1. Pitt, S. P., and O. D. Grace, "Signal Processing by Digital Quadrature Techniques," DRL-TR-68-39, Defense Research Laboratory, The University of Texas at Austin (30 December 1968).

2. Plemons, T. D., "An Echo-Echo Correlation Analysis of Submarine Echoes" (U), ARL-TR-70-7, Applied Research Laboratories The University of Texas at Austin (26 February 1970). (CONFIDENTIAL)

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9 April 1970

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